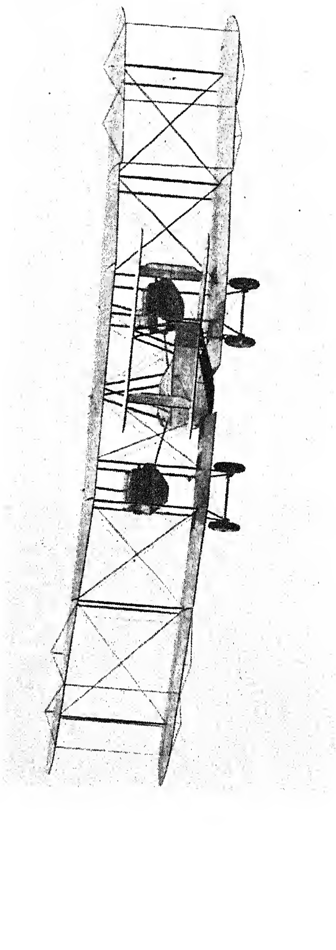

THE BOOK OF THE AEROPLANE

BY

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WITH 58 ILLUSTRATIONS FROM PHOTOGRAPHS, AND DIAGRAMS IN THE TEXT

LONGMANS, GREEN, AND CO. LTD.
39 PATERNOSTER ROW, LONDON, E.C.4
NEW YORK, TORONTO
BOMBAY, CALCUTTA AND MADRAS
1926

P HF-13
113481

22.7.81

Printed in Great Britain

PREFACE

The scope of this book is implied in its title. Aviation is rapidly taking its place among the amenities of civilization, and the time is now very near when flying will cause no more astonishment than the passing by of a motor car. On the great air routes, indeed, those who toil at their daily tasks on the ground have ceased to take the trouble to look up in the sky when they hear the roar of the engines of some great passenger or freight-carrying machine. To them the passing of an aeroplane is a commonplace. Yet twenty-five years ago no man had seen an aeroplane fly, and twenty-five years hence few will have the imagination to realize what the world was like before the air was conquered.

Progress has been rapid, in some ways too rapid, especially during the years of the Great War. Lessons were not only learnt during the war, but many of them have had to be forgotten before progress could be resumed on the right lines. Little by little it is being realized that many of the conclusions of a few years ago must be radically modified in the light of later and more practical knowledge.

This book is brief in its early history deliberately, for much has been written on that history, and the ground has been covered with extreme thoroughness. I have endeavoured to deal more with the aeroplane as it is, how it flies, how it is constructed, what it does, and the necessary organisation on the ground to enable it to take the air with safety.

History has been a little more fully recorded since the Great War, as has description of the precautions taken for safety, types of aeroplanes, the great air routes and the like. There is a great deal of material from which to pick, and the task of choosing has not been an easy one. A full description of the aeroplanes of the world, of the air routes and the like would have taken up many volumes of this size. It is hoped, however, that here will be found a sufficiently representative selection to stimulate the interest of the reader for further knowledge, and to give him a foundation on which to base any further reading. The whys and wherefores are explained in as simple language as possible so that all those who now have no knowledge of aeroplanes can learn with as little worry over technicalities as may be.

I have to thank many who have helped me, particularly Mr Handley Page; Mr J. D. North of Messrs Boulton & Paul; The Bristol Aeroplane Company; Captain P. D. Acland of Messrs Vickers; Mr Fairey of the Fairey Aviation Company; Mr T. O. M. Sopwith; Mr A. V. Roe of Messrs Avro; Rolls-Royce, Ltd.; Mr Oswald Short; Mr T. Stanhope Sprigg, Editor of *Airways*; Mr St Barbe of the De Haviland Company; and the Royal Aeronautical Society.

A certain number of opinions are expressed in this book. These opinions are my own and I am solely responsible for them.

J. LAURENCE PRITCHARD.

1926.

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THE BOOK OF THE AEROPLANE

CHAPTER I

EARLY HISTORY

THE first accounts of the attempts of man to fly are legendary. It is certain that from the earliest times man has tried to emulate the bird with its graceful easy motion through the air, its ability to move rapidly from point to point untrammelled by the inequalities of the land below it. There has always been a feeling of the true poetry of motion in flying which is missing in any other form of travelling. Flying possesses a freedom which no other form of motion has, gives its devotees an exhilaration obtainable in no other way. The ability of the bird to fly and the consequent desire to master the air have, through all the ages, spurred man to steadily increasing efforts to make the air his servant.

Leaving behind the stories which are wholly legendary or at the best of doubtful authenticity, we come to the first man whose studied work to this day is still a subject of discussion, Leonardo da Vinci, surely one of the most remarkable men, if not the most remarkable, of the last thousand years. Artist and engineer, poet and architect, Da Vinci turned his remarkable mind towards the study of flight. He filled pages in his pocket-books with theoretical and practical suggestions, following a close study of birds, and when these notes were translated in 1924 for the Journal of the Royal Aeronautical Society,

they revealed a grasp of fundamental principles which can only be described as amazing considering the time the great Italian lived (1452-1519), and the state of general knowledge of his age.

From the beginning of his work Da Vinci recognised that one of the most important things to study to ensure successful flight was the air itself. "In order to give the true science of the movement of birds in the air," he wrote, "it is necessary to give at first the science of the winds, which we will establish by means of the movements of water. This science will be a means of arriving at the knowledge of the winged creatures in the air and in the wind."

One of the first things Da Vinci did was to make a parachute, and in his notebook he gives the dimensions of such a parachute, which would enable a man to drop safely from any height to the earth. He followed up his experiments with the making of a model of a helicopter, which was successful. His helicopter had, for a motive force, steel springs, and the wings were made of stout paper and wire. Both in these practical attempts to solve the problem of flight, and in the theories which he propounded from his observations of birds, the Italian genius proved himself to be several hundred years before his time.

The work of Da Vinci, though primarily forgotten for some four hundred years, inspired two others to experiment in gliding flight and parachute descents. These two were Paolo Guidotti of Lucca, in the latter half of the sixteenth century, and Veranzio of Venice, in the early part of the seventeenth century. Guidotti actually made a number of wings, with a framework of whalebone and covered with feathers, with which he carried out a series of successful gliding experiments.

In one of these he covered nearly a quarter of a mile. Veranzio confined himself to experiments with parachutes, and though he made a number of successful jumps from heights, he carried his experiments no further.

In the same century that Veranzio experimented, however, three men turned their attention towards solving the problem of flight, and these three men have left their names on the aeronautical roll of fame. They were Borelli (1608-79), Francesco Lana (1631-87), and Robert Hooke (seventeenth century). Borelli wrote a book *De Motu Animalium*, part of which was devoted to a study of the flight of birds. There Borelli was the first to make a serious and scientific study of the mechanical action of a bird's wing. Borelli, however, came to the conclusion that it was impossible for man to fly by means of his own strength, and the further conclusion was erroneously drawn by others, that flight by heavier-than-air machines was impossible. Many of Borelli's other conclusions, sound enough in the main, were not followed up, and further progress on the heavier-than-air machine was retarded until after the invention of the steam engine. But as a pioneer in the theory of aeronautics Borelli ranks very high.

His contemporary Lana was obsessed with the lighter-than-air machine, and the conclusions to which Borelli had come added to the plausibility of Lana's suggestions. In 1670 Lana published a book in which he outlined an ingenious form of airship. His lifting power he obtained by means of four copper globes from which he proposed to exhaust all the air, so making them lighter than the air they displaced. These globes were attached to a basket, and the ship was to be guided

by sails and oars. It was left to a French experimenter (nearly two hundred years after Lana's book appeared) to experiment on the lines of Lana's theory, and to prove once and for all that no metal globe could be made thin enough to withstand the enormous pressure of the air. Lana was a priest, and though in his book he worked out all the details of his airship, even down to giving a method of exhausting the globes, he quaintly adds, "God would rarely never allow disturbances in the civil and political governments of mankind."

Robert Hooke designed a model aeroplane of the flapping wing type, which, though successful, was not carried very far. In the same century, however, Besnier, a locksmith of Sable, constructed a kind of flapping glider. From that time onward, however, till the rising of the hot air balloon of the Montgolfier brothers at Versailles in 1783, little was done towards the conquest of the air. And with that aspect of the conquest of the air, the lighter-than-air method, we are not concerned in this volume.

In the eighteenth century was born a man who was to win the illustrious title of "the father of British aeronautics," Sir George Cayley. Cayley was a wealthy Yorkshireman, and could afford to spend the time and money on the many sides of science which interested him, and none interested him more than the science of aeronautics. He wrote much on the subject, and much of what he wrote proved that he was many years in advance of his time. In 1796 he made a successful model of a helicopter, and he was one of the first men to realise the advantages of the now established cambered wing, and to suggest methods by which a possible aeroplane could be made stable in the air.

He suggested the use of the tail and the rudder and of the angle at which the wings of an aeroplane are set, the dihedral angle, for lateral stability.

Cayley studied the problem scientifically, studied what power would be required to sustain steady horizontal flight, and came to the conclusion that such power (in relation to the weight of the engine giving it) did not then exist. He practically stated that with the steam engine as it existed in his day flight in a heavier-than-air machine was impossible, and subsequent events bore him out to the full. But he actually anticipated the coming of the internal combustion engine, and there is this to be said to the everlasting credit of the man, that he was the first to point out the true path to scientific progress in the study of aeronautical problems, that he was the first to establish certain principles which are now commonplaces.

Sir George Cayley died in 1857, but before that event another pioneer had stepped on the stage and was playing his part on the conquest of the air. In 1842 W. H. Phillips made a flying model with revolving fans. These fans were made to spin by causing a jet of steam to impinge on them, the steam being produced by a combustion of charcoal, nitre and gypsum. The machine actually travelled across two fields but crashed on landing, and Phillips did not follow up his invention. But it is worth noting as the first model which flew under steam power.

We are now coming to that period when men were beginning to realize that the possibility of flight by heavier-than-air machines was something within the range of practical politics, something which might be achieved by patient endeavour and constant study. In 1840 Henson began his experiments on a monoplane,

and in 1842 entered a patent (No. 9478) which described a machine which is not very far from the monoplane of to-day in the general principles of its construction. The materials suggested for its construction were spars of bamboo and hollow wood, with wire bracing. The planes were to have a total lifting surface of 4500 square feet with a triangular tail of 1500 square feet. The engine was to be one of 25 to 30 horse-power, driving two six-bladed propellors.

Henson became associated with Stringfellow, who, later, when Henson abandoned further experiment, carried on alone. Between 1846 and 1848 Stringfellow built a large model aeroplane which flew. It had a span of 10 feet and a total sustaining area of 14 sq. feet. The two propellers were driven by a small steam engine and the total weight of the model was 8 lbs. The first time the machine flew the tail was set at too great an angle so that it climbed too rapidly and ultimately crashed.

In 1866 was founded the Aeronautical Society of Great Britain, and Stringfellow, who had allowed his experiments to lapse, once more entered the field. In 1868 at the first Aeronautical Exhibition, held at the Crystal Palace, he showed a model of a triplane which he had constructed. This model had a supporting surface of 28 sq. feet, and weighed, with engine, boiler and fuel, 12 lbs. The engine developed one third horse-power, and Stringfellow was awarded £100 for the construction of a steam engine with the highest power to weight ratio. When, in 1883 John Stringfellow died, he left an imperishable name in the history of aeronautics. He realized to the full the value of the cambered wing, put to the practical test many of his theories of construction, and it is certain that if

the internal combustion engine had been in existence in his day he would have anticipated the remarkable achievements of the Wright Brothers by fifty years.

But Caley, Henson, Stringfellow and others were laying steadily but surely the foundations for the science which was in the early years of the twentieth century to receive such a remarkable impetus in its growth. On the Continent as in England, interest in aeronautics was steadily increasing, and men were visualizing the time when air transport would be as common as road transport. A Frenchman, D'Amecourt, exhibited a steam model of a helicopter at the Aeronautical Exhibition of 1868, and another Le Bris, a French sea captain, carried out some remarkable experiments in a full sized glider, rising on his first gliding flight to a height of 300 feet.

In the early seventies and onwards Otto Lilienthal began his famous gliding experiments, and made a more detailed study of the properties of curved wing surfaces than had as yet been made. In 1889 he published his *Bird Flight as the Basis of Aviation,* the results of his experiments on curved wing surfaces and his studies of the flight of birds. In 1891 he built his first glider, and from that day until 1895, when he met his untimely death, he carried out over 2000 gliding flights. His first glider had a supporting surface of 100 square feet. His last glider was a biplane. Lilienthal carried out his experiments near Berlin, on a stretch of country so flat that he had to build an artificial hill from which to begin his glides. He controlled his glider by moving his own body. Lilienthal's experiments had this great value, that they taught a method of control of an aeroplane in the

air against that time, which was rapidly coming nearer, when a power unit could be added which could make a machine actually fly. The experiments of Lilienthal were of the utmost value to those who immediately followed him.

Contemporary with the German experimenter was an Englishman named Pilcher. His first monoplane was completed in 1895, after which he paid a visit to Berlin and watched Lilienthal before gliding in it. Pilcher built a number of gliders and made many flights before meeting with a fatal accident owing to one of the guy wires of his tail plane snapping. Dying on 2nd October 1899, Pilcher in his four short years of experiment had made his name as famous as that of his brilliant contemporary Lilienthal.

Meanwhile Octave Chanute and Montgomery in America had become interested in the experiments of Lilienthal, and these two were to sow the seeds of ambition in the United States which were to bear fruit in the brilliant achievements of the Brothers Wright but a very few years later. Chanute had been interested in aeronautics for some forty years before he began his experiments, and he was well over sixty years of age when he boldly decided to attempt the conquest of the air. He at once saw that one of the chief problems he would have to solve was the maintaining of equilibrium in the air, and to this he first turned his attention.

He began his experiments on the shore of Lake Michigan, and here in 1896 and 1897 he carried out glides with a biplane and a machine having five tiers of wings. With the latter several hundred successful glides were undertaken. With the Chanute method of construction and tail balancing far less actual

movement of the operator was necessary to keep control than had been the case with the gliders built by Lilienthal. But Chanute soon found that the biplane form of construction gave far better results than that with five super-imposed planes. His glides were longer and many were carried out in winds up to 30 miles an hour. The experiments of Chanute proved one thing and that was that a glider could be built that was perfectly stable. So stable, indeed, were his gliders, that he allowed strangers to glide under his instructions, and no accident was recorded. That in itself is a monument to his genius.

Professor John J. Montgomery built a flapping wing machine as early as 1883, and followed it in 1884 and 1885 with gliders having curved surfaces. Montgomery, like Chanute, insisted first of all upon the importance of stability, and he made many models to obtain the information he desired. "These models," he wrote afterwards in describing his experiments, "were tested by dropping them from a cable stretched between two mountain tops, with various loads, adjustments and positions. And it made no difference whether the models were dropped upside down or any other conceivable position, they always found their equilibrium immediately and glided safely to earth."

Montgomery had full-sized gliders made as a result of his experiments and launched them from balloons, he and his assistants making some very remarkable glides. The flights were brought to an end by the great San Francisco earthquake of 1906 and the death of one of his assistants while gliding from a height of 2000 feet. He himself was finally killed in 1911 while carrying out further gliding experiments. But he had

lived long enough to see that man had at last conquered the air.

There were many pioneers in the closing years of the nineteenth century whose work can only be briefly referred to here. Horatio Phillips in 1884 was one of the first to study the lifting power of curved surfaces from a scientific point of view. In 1886 a Frenchman, Clement Ader, built a machine with a wing span of 46 feet, driven by a steam engine of between 26 and 30 horse-power. On 9th October 1890 he is stated to have flown some 160 feet, when his machine was wrecked. Seven years later, in the presence of the French Military authorities, Ader is stated to have flown 1000 feet, when his machine was again wrecked.

At about the same time Sir Hiram Maxim in England was turning his attention to the great problem. He realized from the beginning that one of the things which prevented flight was the great weight of the engine compared with its horse-power, and he tried to get over that difficulty by building a large aeroplane. His machine had a wing surface of 4000 feet. There were five long and narrow planes projecting from each side and a main central plane. Maxim calculated that his machine would lift 8000 lbs., of which the engine with boiler and water accounted for 600 lbs.

Maxim ran his machine along specially constructed rails so that he could experiment with the machine and ascertain its lifting power before going on finally to free flight. Maxim's giant machine actually lifted itself from its track, but the machine was wrecked during further experiments and Maxim abandoned it.

Before passing to a consideration of the work of the brothers Wright, the experiments of Professor S. P. Langley must be described. Langley only missed the

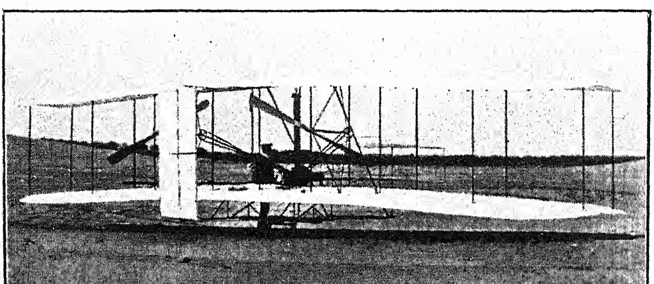
fame the Wright brothers achieved by sheer ill-luck. He had the advantage over many of his predecessors of being a scientist, and as a scientist he carried out a series of patient investigations before attempting the actual practical problem of flight. For several years, in fact, Langley experimented, and with a number of models, elastic driven, showed that flight was possible. Langley found, as previous experimenters had done, that the engine problem was one of almost insuperable difficulty. No engine had been constructed up to that time which was suitable, and Langley decided to design one himself. He was successful in that he provided a number of models with steam engines of his own construction and flew them successfully. On 6th May 1896 one of his models flew over 3000 feet, making three complete circles, and in November of the same year another flew three-quarters of a mile at a speed of 30 miles an hour. By then Langley was proving that mechanically propelled flight was possible.

In 1898 the internal combustion engine had so far advanced in design that Langley came to the conclusion that it was the motive power for which he was looking. He placed the actual design of the engine he intended to use in the hands of Charles M. Manley, his engineer. Manley produced an engine developing 50 horse-power and weighing only 120 lbs. After many tests Langley's aeroplane was ready for its first flight on 7th October 1903. It had a supporting surface of 1040 feet, weighed 730 lbs. and was driven by two propellers. The trial was carried out over the river Potomac, but was unfortunately unsuccessful, as part of the machine caught in the launching apparatus and caused it to plunge into the water. On 8th December another test was made, and again the machine

was wrecked in launching. There is little doubt that the machine Langley built was capable of carrying a man, and but for the unfortunate accidents in launching, for which Langley cannot be justly blamed, he would have been able to claim to have been the first man to produce a man-carrying power-driven aeroplane. The American Government refused to advance any further money for the experiments. Langley's great, even glorious failure was on 8th December 1903. On 17th December 1903, the Wright brothers rose in the air with a power-driven machine.

Man had at long last conquered the air.

Wilbur Wright.



The Original Wright Biplane.

PLATE II.

CHAPTER II

The Wright Brothers and the Wright Machine

Among those who read the brief paragraph in the American newspapers announcing the death of Lilienthal were Wilbur Wright and his brother Orville. That little paragraph was to have an incalculable effect on the progress of aeronautics, was to make the names of the Wright brothers as famous as any names in history.

Wilbur Wright was born near Newcastle, Indiana, on 16th April 1867, and his brother Orville at Dayton, Ohio, on 19th August 1871. There were two other brothers in the family, and a sister, Katherine. The latter played no insignificant part in the success of her two famous brothers. The Wrights were fortunate in having for their father a man of broad views, a man who encouraged original thoughts, a man who did not try to force his sons to follow any stereotyped form of occupation. In their early years the brothers showed a keen interest in journalism, and at the age of seventeen Orville Wright began the publication of a local weekly newspaper of which his brother Wilbur was the editor. This publication was followed by an evening newspaper and a weekly magazine for which Wilbur Wright wrote extensively. That the two had a mechanical turn of mind, as well as the imaginative one shown by their journalistic enterprises, is shown by the formation of the Wright Cycle Co., which proved to be very successful.

Both the brothers had always been keenly interested in the possibility of human flight, but it was not until

the tragic death of Lilienthal, whose experiments they had followed eagerly, that they began to turn their attention seriously towards the solution of the problem. Their great countryman, S. P. Langley, had publicly declared his belief that the age of flying was rapidly approaching, and his scientific reputation was high enough to make the brothers feel that in attacking the problem they were not attempting something which was inherently impossible, but were attempting something which was soluble, though its solution was one of great difficulty.

"My own active interest in aeronautical problems dates back to the death of Lilienthal in 1896," said Wilbur Wright speaking in 1901. "The brief notice of his death which appeared in the telegraphic news at that time aroused a passive interest which had existed from my childhood, and led me to take down from the shelves of our home library a book on *Animal Mechanism* by Professor Marey, which I had already read several times. It seemed to my brother and myself that the main reason why the problem had remained so long unsolved was that no one had been able to obtain any adequate practice. We figured that Lilienthal in five years of time had spent only about five hours in actual gliding through the air. The wonder was not that he had done so little, but that he had accomplished so much. It would not be considered at all safe for a bicycle rider to attempt to ride through a crowded city street after only five hours' practice, spread out in bits of ten seconds each over a period of five years; yet Lilienthal with this brief practice was remarkably successful in meeting the fluctuations and eddies of wind gusts."

Like all men of genius the brothers Wright had an

infinite capacity for taking pains. From the first they realized that the problem was not to be solved by building something which would glide. That had been done over and over again, and though progress had been made it had not been great enough to justify an assumption that flight, sustained and stable flight, was much nearer. Once the two had decided that they would attempt to fly they thought of nothing else. Every possible book they could find on the subject they studied with the greatest care, and they built gliders solely to test the statements which had been made by various writers. They took very little for granted, preferring to test everything for themeselves, and so gaining an experience which was to prove of the greatest value to them when they were carrying out their final experiments. They found during the course of their early work that many of the statements and figures given in books were very far from the truth, and they decided that the only way to be certain was to obtain figures for themselves.

For this purpose they built themselves a small wind tunnel and made thousands of tests of small curved planes to obtain the basic figures of the lifting power and resistance of wings before they began to build gliders of their own design. And the results of their patient work of figuring were quickly seen when they began their full scale experiments.

The two brothers were fully aware of the difficulties which faced them, and perhaps these cannot be better expressed than by Wilbur Wright himself. "If I take a piece of paper," he said in a lecture in 1901, "and, after placing it parallel with the ground, quickly let it fall, it will not settle steadily down as a staid, sensible piece of paper ought to do, but it insists on contraven-

ing every recognized rule of decorum, turning over and darting hither and thither in the most erratic manner, much after the style of an untrained horse. Yet this is the style of steed that men must learn to manage before flying can become an everyday sport. The bird has learned the art of equilibrium, and learned it so thoroughly that its skill is not apparent to our sight. We only learn to appreciate it when we can imitate it.

"Now, there are only two ways of learning to ride a fractious horse; one is to get on him and learn by actual practice how each motion and trick may be best met; the other is to sit on a fence and watch the beast awhile, and then retire to the house, and at leisure figure out the best way of overcoming his jumps and kicks. The latter system is safer, but the former, on the whole, turns out a larger proportion of good riders.

"It is very much the same learning to ride a flying machine; if you are looking for perfect safety you will do well to sit on a fence and watch the birds, but if you really wish to learn you must mount a machine and become acquainted with its tricks by actual trial. The balancing of a gliding or flying machine is very simple in theory. It merely consists of causing the centre of pressure to coincide with the centre of gravity. But in actual practice there seems to be an almost boundless incompatibility of temper which prevents their remaining peaceably together for a single instant, so that the operator, who in this case acts as peacemaker, often suffers injury to himself while attempting to bring them together."

Both Wilbur and Orville Wright realized that practice, practice, practice was required to learn to

fly. They marvelled that, with the very little practice Lilienthal had had, he had done so well. But where Lilienthal had only a few seconds to practise each time, the Wright brothers determined to practise by the hour.

"We thought that if some method could be found by which it would be possible to practise by the hour instead of by the second there would be hope of advancing the solution of a very difficult problem," said Wilbur Wright. "It seemed feasible to do this by building a machine which would be sustained at a speed of 18 miles per hour, and then finding a locality where winds of this velocity were common. With these conditions, a rope attached to the machine to keep it from floating backward would answer very nearly the same purpose as a propeller driven by a motor, and is would be possible to practise by the hour, and without any serious danger, as it would not be necessary to rise far from the ground, and the machine would not have any forward motion at all."

The Wrights accordingly fixed on a place called Kitty Hawk in North Carolina, a little settlement on the strip of land which separates Albemarle Sound from the Atlantic Ocean. There they took up their quarters in the summer of 1900 and built a glider with 165 square feet of supporting surface. From tables published by Lilienthal they calculated that their glider would lift itself and a man in a wind of 21 miles an hour with the planes inclined at an angle of only three degrees to the wind.

But their very first experiment showed them that something was wrong. Actually the wind was blowing between 25 and 30 miles and hour, but the angle of the wings was nearly 20 degrees. But one

important discovery was made. Up till that time those who had been experimenting with gliders had balanced them laterally by shifting themselves about on the glider, an admittedly unsatisfactory method. The Wrights substituted a method of twisting the surfaces, which they found as effective. But they were disappointed that their glider would not lift a man except in a comparatively high wind, and, distrusting the published figures of the lifting power and resistance of curved planes, they began to obtain figures for themselves, and to obtain them, moreover, with the full-sized glider, something which had not been previously attempted.

The two brothers immediately made the remarkable discovery that neither the lift nor the resistance were anything like as great as theory had led them to suppose they would be, and they decided to make fresh planes with an entirely different camber. In the meantime, however, they carried out a series of gliding experiments to accustom themselves to being in the air. As a result of these gliding experiments, the Wrights came to the conclusion that a small surface set in front of the main planes, a rudder, and the twisting of the wings would enable them to control the glider completely in the air.

In 1901 a new glider was built with a curvature of one in 12 as against the one in 22 with which they had previously experimented. The area of the new glider was increased to 308 square feet, the largest, up to that time, ever built by an experimenter. On 27th July 1901, the glider went up and made a glide of 300 feet, a very remarkable performance, considering its size and unknown possibilities. It was found that the small forward balancing surface, instead

of the usual tail, acted very well, but the machine was not quite so stable as the one built the previous year. An alteration was made to the shape of the wing surfaces, reducing the camber, and many long glides were made in winds of 11 to 14 miles an hour. Gradually glides were made in winds of greater strength and more and more confidence was gained, while further experimental figures were obtained to find out what the total resistance of the glider was in a wind. These figures were naturally of great importance, as the resistance became a leading factor in flying the machine once an engine was placed in it. All this time the two brothers were not content with carrying out gliding experiments. They flew the glider as a kite and measured the pull on the ropes holding it not only in varying winds, but in varying positions of the glider, so that they slowly began to find out what forces were acting on the glider under the varying conditions which they might expect to meet when actually flying. It was laborious work in many ways, but their patient observations bore all the fruit the two so well deserved. For the first time, indeed, flight was being made a scientific study by two thoroughly practical investigators. They were determined to learn all they could about the new form of locomotion before they decided to take to the air in a power-driven machine. They counted no time wasted in obtaining the data for their new task, for it meant that when they did attempt to fly that attempt would be a successful one.

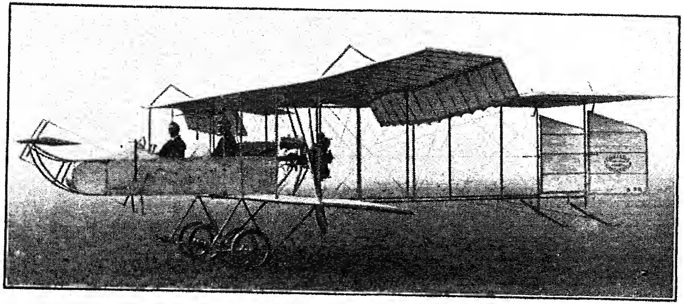
In the following year, in September and October 1902, nearly 1000 gliding flights were made, many of them over 600 feet in length, and in winds of over 30 miles an hour. And then the brothers began to

discuss the possibilities of putting an engine in the glider and using a propeller to drive it forward.

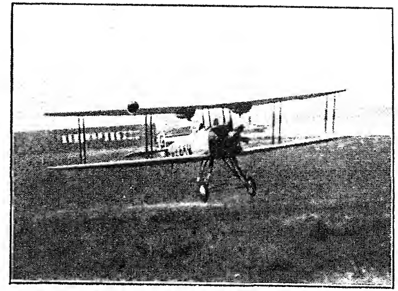
"What at first seemed a simple problem became more complex the longer we studied it," wrote Orville and Wilbur Wright in 1908. "With the machine moving forward, the air flying backward, the propellers turning sidewise, and nothing standing still, it seemed impossible to find a starting point from which to trace the various simultaneous reactions. Contemplation of it was confusing. After long arguments we often found ourselves in the ludicrous position of each having been converted to the other's side, with no more agreement than when the discussion began."

The problem seems a simple one now—thanks to those two arguing and experimenting in those early days—but it must have been a terribly difficult one when there was no human experience upon which to go.

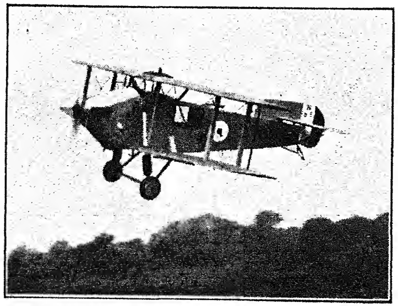
The first flight under power was made on 17th December 1903. Only five people were present beside the two brothers who were inaugurating a new era for the world. It is worth while recording the names of those present on that historic occasion. They were John T. Daniels, W. S. Dough, A. D. Etheridge, W. C. Brinkley and John Ward—seven people in all. That flight which was destined to have such far-reaching results, lasted only 12 brief seconds. It was the first authenticated flight in the history of the world in which a machine carrying a man had raised itself by its own power in the air in free flight, had sailed forward on a level course without reduction of speed, and had finally landed without being wrecked. This flight was followed by two a little longer, and a fourth of 59 seconds, nearly a whole minute! During that time a



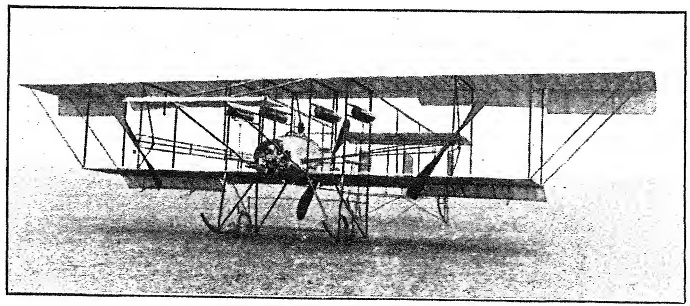
1913 Short Biplane.



Avro 504 N.



Avro Bison Fleet Spotter.



First Twin-engined Aeroplane ever built (Short).

PLATE III.

distance of 852 feet was covered against a 20 mile an hour wind. Not a single newspaper reporter was present on that cold raw December day, an ironic comment in itself on the attitude which the world adopted, less than a quarter of a century ago, to what, in that brief interval of time, has become the commonplace.

The first machine to fly was of biplane construction, driven by two screws set out in the wings and chain driven. The machine was partly shot into the air, from a special rail, to give it an initial speed, there being no wheeled chassis which would allow it to taxi along the ground in the way which is now familiar. The engine was constructed by the Wrights themselves, it having been found impossible to obtain the exact type of engine they required. It was a four-cylinder four-cycle motor.

After the last flight, while those seven men were engaged in talking about the most wonderful thing which had happened since the invention of the steam engine, the machine was bowled over by a sudden gust of wind. An effort was made to right it, but the wind was too strong, and the damage which was caused ended the experiments for the time being.

In 1904 the brothers continued their experiments on Huffman Prairie, eight miles east of Dayton. A new machine had been built, similar to the first, but heavier and stronger. To the first flight of this new machine every newspaper in Dayton was asked to send a representative. Altogether some fifty people were present. Unfortunately the wind was only blowing at three to four miles an hour, the engine was not working properly, and the machine failed to rise in the air. The reporters did not, even then, believe

flying was any nearer than it had been fifty years before, and afterwards when they heard that flights of several minutes were being made, they did not take the trouble to attend. The world had waited so long, had seen so many failures, that when success was reached at long last it was sceptical.

During all the preliminary flights the machine had been flown only in more or less straight paths. Although many problems of control had been solved, the Wright brothers were still uncertain what exactly would happen when they tried to turn the machine in the air with a wind blowing. But it was no use having a machine which would only fly in a straight line, or it would have to land every time it wanted to turn! Three trials were made to fly in a circle, but it was not until the fourth attempt that a complete circle was made. After that the machine was repeatedly circled round until complete mastery of it was obtained.

The circling was carried out by means of the patented interlocking of the wires which warped the wings and controlled the vertical rudder. When it was required to circle to the left, for example, the vertical rudder was moved to the left, and the right wing was warped slightly upwards and the left wing slightly downwards. This made the machine tilt so that the left wing was lower than the right, and the machine began to slip to the left. In doing so, however, the air struck the vertical rudder at a greater angle than was necessary to compensate for the difference in resistance of the right and left wings. This caused the tail to lag behind, and so the lateral movements of the main aeroplane sidewise as the result of the tipping, became combined with a rotary movement about its vertical axis, and the machine flew in a circle.

In 1904 about one hundred flights were carried out, but though all were successful, the brothers were not quite satisfied that the machine was fully controllable, as it did not always respond as promptly as was expected. During these flights the machine had never flown more than about ten feet from the ground, in case control was lost and it was made impossible to land safely. But the disadvantage of flying so low was that when an uncontrollable position was reached the machine landed before the method of regaining control could be found. Actually the cause of the trouble was loss of flying speed in most cases, and the trouble was correctly diagnosed and allowed for. In 1905 flights of 11, 12, 15 and 24 miles were made. The age of flying had begun.

During the next two years the Wrights devoted a large part of their time to business negotiations and the construction of new machines, resuming their flying experiments in May 1908 to test whether their machine was capable of carrying out a contract they had made with the United States Government. By this contract they were called upon to produce a machine which would fly 125 miles at 40 miles an hour and carry two men.

The machine used was practically the one made in 1905. The framework of this early machine was made of larchwood, and the span of the machine was 40 feet. The motor used developed 12 to 15 horsepower and weighed 240 lbs. The wings were covered with ordinary good quality muslin, and the chassis consisted of skids or runners like those of a sleigh. The total weight of the machine was 925 lbs. including the motor. The pilot lay face downwards, and in the machine specially built for the United

States Government two seats were provided, one for the pilot and one for the passenger.

Before continuing the story of the Wright brothers, something must be said about the attempts to fly which were being made in the years 1899–1908 in France and elsewhere. While the Wrights were experimenting and gliding and ultimately flying, there were many others who were engaged in attempts to solve the great problem. Orville and Wilbur Wright, indeed, only won the right to be called the first airmen by a very narrow margin.

In France, Captain Ferber, in 1899, began a series of gliding experiments at the Military School at Fontainebleau, and in 1905 he made his first attempt to fly on a power-driven aeroplane. Like the Wrights, Captain Ferber was a scientific investigator, and his unfortunate death through a flying accident in 1909 was a great loss to aeronautics. Contemporary with him were Henri and Maurice Farman, Santos Dumont, Hubert Latham, Bleriot, Voisin and a host of others.

The early Voisin machines were cellular in their construction, like a series of boxes fastened together. They were biplanes with four vertical panels between them. The propeller was behind the main planes, and the tail, also of box-like construction, was carried on outriggers. In front of the machine was an elevator. A wheeled chassis was employed. The total weight of the machine was 1400 lbs. and its lifting surface was 535 square feet. The total span was 33 feet for the main planes and 8 feet for the tail. The engine was a 50 horse-power Antoinette. Nearly all the framework was made of ash. Voisin has the credit of being the founder of the first aeroplane factory in the world.

One of the first men to learn to fly on the Voisin

machines was Henry Farman, and he followed up his experience by building an aeroplane to his own designs. With this machine Paulhan won the famous London to Manchester flight, more fully dealt with in another chapter.

The first officially recorded flight in Europe was made by Santos Dumont on the 23rd October 1906. For this flight Dumont won a prize for the first flight to be made over a distance exceeding 25 metres. Actually, the distance covered was 164 feet. A year previously the Wrights had flown 24 miles, but the world was not yet ready to believe in their achievements! The successful flights of Orville and Wilbur Wright, in fact, had attracted very little attention, though they were among the most important events in the history of the world. This was partly due to the modesty of the inventors themselves, and partly to the far-away spot in which they carried out their experiments.

There is not space here to deal with all the accounts of the feverish activities of flyers and would-be flyers in the years 1906–1908. Despite the many authentic accounts which had come across the Atlantic of the achievements of the Wrights, there were many who believed that these achievements had been grossly exaggerated until in August 1908 Wilbur Wright made his first flight above European soil.

The 8th August 1908, on the Hunandières Racecourse near Le Mans, was a day which will live in history, perhaps even more than that remarkable day in December 1903 when the Wright machine first flew under its own power. All the world knew of the Wrights by now, and all eyes were, metaphorically, focussed on the man and his machine. No one quite

believed what the Wright brothers had claimed, but though he only flew for one minute forty-seven seconds in public, covering a mile and a quarter, his performance for ever silenced the critics. Three days later Wilbur Wright flew for four minutes, during which he executed all kinds of manœuvres, and showed such complete control over his machine that M. Delagrange, who witnessed his flight, exclaimed "We are beaten."

On the 21st September Wilbur Wright astounded everyone by remaining in the air for over an hour and a half, and flying 61 miles, and afterwards he made many flights of an hour and over. The progress made by aviation during 1908 was indeed remarkable, and almost wholly due to the inspiring example of Orville and Wilbur Wright. Their flights only made the enthusiasm of such pioneers as Delagrange, Henry Farman, and others all the greater. Large prizes were being offered everywhere to encourage the fliers, and Messrs Michelin, in particular, offered £10,000, the income from which was to form an annual prize for the flight of longest duration. It is appropriate that the first man to fly, Wilbur Wright, was the first man to carry off the first prize offered for an endurance record. This flight lasted 1 hr. 53 min. 59 secs.

The year 1909 saw another great leap forward. In this year was held the first British Aero Show at Olympia. The Channel was flown by Bleriot, the Rheims Aviation Week was held (the first of many such meetings), the first contest took place for the Gordon-Bennett Aviation trophy, flying meetings were held at Blackpool and Doncaster, and J. T. C. Moore-Brabazon won the £1000 prize offered by the *Daily Mail* for the first circular flight of one mile on a British machine.

Flying had ceased, in a single year, to be the joke of half the world. In twelve months its wonderful possibilities had been proved, and people were already beginning to talk glibly about the aerial age, when everything would be transported by air, and all wars would be fought in the air.

They were learning to fly before they could walk, to paraphrase the old adage, and many of the prophesies of those early days proved ludicrous. Everyone was talking of the future. Only one man did not talk, and that the man who, with his brother Orville, had brought flying into the range of practical politics.

"The bird which talks most is the parrot," he once observed, "and it is the bird which flies least."

CHAPTER III

How an Aeroplane Flies

Before any description of the way an aeroplane flies can be given, it is necessary to outline certain fundamental principles of the flow of fluids past obstacles.

The air is a fluid just as much as water is, and it will be convenient here to consider certain properties of the air.

First of all air has weight, one cubic foot of air at sea-level and at a temperature of 32° F. weighing ·0807 of a lb. The density of air decreases with the height above sea-level. That is to say, the higher one goes the less a cubic foot of air weighs, an important fact when the problem of an aeroplane rising to a great height and flying at that height is considered. As the air has weight it offers resistance to the movement of any body through it, just as water does to the passage of a submarine.

Air has a property called viscosity. This property corresponds to friction in solids, so that when air is flowing over a flat plate, for example, that layer of air next the surface of the plate is more retarded than layers of air farther away. This retardation of the air layers near the surface of a body over which it is flowing sets up eddies which are of great importance in flying.

The flow of air may be represented diagrammatically by means of lines which give some idea of the actual flow. Fig. 1 and Fig. 2 show the way these stream-lines are represented. These lines are not just theoretical, but they can be shown in practice to represent

very much what does happen when air flows or streams past a flat plate held in the direction of the flow or at right angles to it. This can easily be shown by allowing a certain amount of smoke to enter the air stream, when the stream is made visible.

Now consider what happens when the air flows past a flat plate, as in Fig. 1. L.E. is the leading edge of

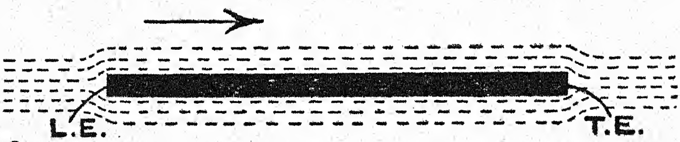


Fig. 1.

the plate, the edge on which the air stream first impinges, and T.E. is the trailing edge, the edge at which the air stream leaves the plate. When the air stream strikes the edge of the plate L.E. the particles of air are crowded up together. There is, in fact, an increase of pressure. At T.E., on the contrary, since the air streams on each side of the plate do not meet or unite again until they are some little distance from the edge, there is a decrease of pressure. A partial vacuum is formed, in fact, and has a sucking effect as it were. If the air were still and the plate were moved through it, exactly the same effects occur, as though the plate were still as shown and the air is flowing past it. So this sucking effect and the increased pressure on the leading edge of the plate produce a resistance to the plate as it moves through the air. And the faster the plate moves through the air the greater is the increase of pressure in front and

the decrease of pressure behind and the greater, therefore, the resistance.

Suppose now that the flat plate is held at right angles to the flow of air, as in Fig. 2, or, what is exactly the same thing, suppose the plate is moved through the air with its main surface at right angles to the direction of motion. On one side of the plate the particles of air would be pressed together and on the other there would be a series of eddies. This may be explained by considering a streamline of air which just passes over the edge of the plate. At the moment its direction is away from the plate. It is being deflected and tries to travel outwards. But it is prevented from actually travelling outwards by the viscosity of the neighbouring layers of air, and it bends inwards again behind the plate and a whirlpool is formed. Many such eddies or whirlpools are formed behind the plate, depending upon the rate at which the plate is moving through the air, or, what is the same thing, the rate at which the air is flowing past the plate. Obviously, with a very large plate indeed, there must be in the centre part of the back a region of comparative calm. This phenomenon occurs so widely in nature as almost to pass unnoticed. When a wind is blowing, it is natural to shelter behind some object, a small hill, a wall and so on. But when a strong wind is blowing it will be often noticed that even on the sheltered side the wind sometimes seems to be coming from all directions at once, as it were. These are, in fact, the eddy currents or whirlpools.

Naturally it is very important to understand the exact nature of these currents behind an object past which air is flowing, but unfortunately it is not possible always to predict their nature with objects of different

shapes and with varying air flows. Theories have been advanced to account for much of the flow, particularly with regard to objects of certain shapes, as spheres and the like, but the mathematics of such theories is extremely difficult and far beyond the scope of this book.

However, there is one thing which can at once be stated about these whirlpools or eddies. They are very disadvantageous to the motion of an object through the air. They waste energy. The more whirlpools or eddies there are the greater the waste of energy, and the less there is left for the proper purpose for which it may be intended. One of the chief things to be considered in making an aeroplane, indeed, is to construct it in such a way that these eddies are reduced to a minimum. The eddies are indicated roughly by the curved arrows in Fig. 2, but actually they are much

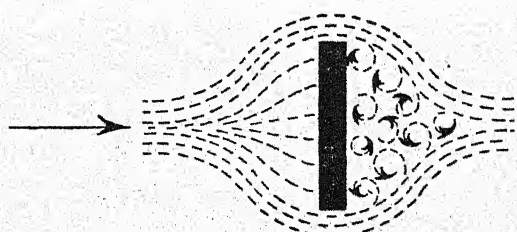


FIG. 2.

more complicated in practice than is indicated by the arrows. On the side of the plate facing the air current there will be an increased pressure, and on the side away from the air current there will be a decreased pressure. The resistance the plate offers to the air

flow is proportional to the difference between these two pressures.

The resistance an object offers to the air stream is proportional to the square of the velocity of the stream of air. If the object is moved twice as fast through the air, or the air flows twice as fast past it, the resistance is quadrupled.

The two positions of a flat plate, edge on to the air flow and at right angles to it, have been considered. Now consider the far more important case of a flat plate inclined at some angle to the air stream intermediate between 0° and 90°. An understanding of what happens in this case is necessary before the action of an aeroplane wing can be grasped.

Fig. 3 shows a flat plate in the air stream, the plane of the plate making an angle, say, with the direction

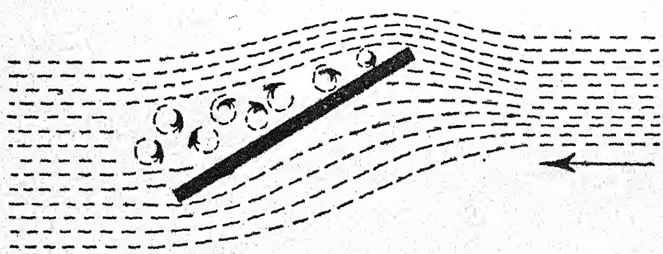


FIG. 3.

of the air flow. The air is deflected by the plate very much in the way shown in the figure, and eddy currents are formed behind the plate. Now it is clear that in order to keep the plate at the same angle to the air stream some force must be applied to the plate. This force, when the angle of the plate to the air stream

(the angle of incidence) is small, is practically at right angles to the plane, and is indicated in Fig. 4 by the

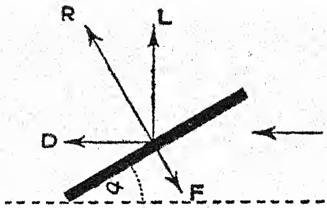


FIG. 4.

arrow F. R is the equal and opposite reaction, that is, the force of the air stream on the plate.

Now any force can be divided into two forces at right angles to one another. If a man is pulling on a rope, for example, the path he exerts can equally well be exerted by two other men pulling on ropes in directions at right angles to one another. When one force is broken up in this way into two other forces at right angles the force is said to be resolved into components. It is often very convenient to split a force up in this way, and particularly is this the case when the forces on an aeroplane are being considered.

So the force R can be resolved in two directions at right angles, one horizontal and one vertical, L and D in the figure. The force L indicates the lifting power of the air stream, and the force D the resistance, or drag, as it is more generally called, of the plate to the air flow. If the force L is equal to the weight W of the plate, then the plate will not move upwards or downwards. If L exceeds W, then the plate will move upwards, and if it is less than W it will drop down-

wards. This lift component is, therefore, one of great importance in aeronautics, for upon it depends whether an aeroplane can be made to rise from the ground or not.

The drag component, D, is very important, too, for the engine which is used must overcome this resistance, and the greater the resistance the more unnecessary power of the engine is used up in overcoming it. The aim of all aeroplane designers is to make the lift component of their aeroplanes as high as possible and the drag component as low as possible. But the flat surface is much too inefficient for this purpose as its lift is too low and its resistance too high.

Many of the early observers who studied the flight of birds noticed that their wings were not flat surfaces, but curved ones, and it was soon realized that part of the secret of flying must lie in a curved or cambered surface. The use of such a cambered surface at once lessened the amount of eddying on the trailing edge, the edge at which the air stream leaves the surface. And the decrease of eddies meant a decrease of drag or resistance. In other words, the ratio of the lift to the drag, the L/D ratio, as it is generally written, is greater with a cambered wing than it is with a flat-surfaced wing.

In the modern aeroplane both the top and the bottom surfaces of the wings are curved, the curve on the upper surface being considerably greater than on the lower surface. Upon the way these two surfaces are curved depends very largely the efficiency of the wing for lifting, and there are many types of curved surfaces now in existence. As will be explained later, it is not easy to find a surface which is efficient in every way, and special surfaces have been designed for particular purposes.

The distribution of the air pressure over a cambered wing is very different from that over a flat wing, and this distribution varies very considerably as the cambered wing or aerofoil is held at different angles to the direction of air flow. Fig. 5 represents

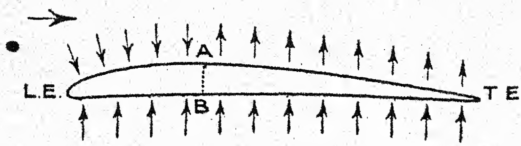


FIG. 5.

a section of an aerofoil, the leading edge L.E. being considerably thicker than the trailing edge T.E. The arrows show how the pressure is distributed over the aerofoil. Those arrows pointing towards the aerofoil show where the pressure is greater than atmospheric pressure, and those away from it where the pressure is less than atmospheric pressure. It will be noticed that the pressure on the underneath surface is greater than atmospheric pressure, showing that there is a lift on that surface. The pressure is also greater than atmospheric pressure at the leading edge L.E. and on the upper surface nearly as far as the point of maximum depth, A B, of the aerofoil. From that point on the upper surface, however, to the trailing edge T.E., the pressure is less than atmospheric, showing that there is a lift on the upper surface as well as on the lower. The maximum value above atmospheric pressure is found at the nose of the aerofoil, and the maximum value below atmospheric pressure at a point on the upper surface just in front of the line A B. The position of this point of greatest depth is clearly very

important, and many experiments have been carried out to ascertain the best position and the best depth in relation to the curves of the upper and lower surfaces.

The general distribution of pressure on the two surfaces varies with the angle of incidence, that is, the angle the aerofoil makes with the direction of the air flow. At some angles the pressure on the upper surface may be less than atmospheric pressure almost up to the nose. The resultant of all the pressures on the aerofoil is the total force acting on the aerofoil, and the position at which it may be considered to act is known as the centre of pressure. The centre of pressure varies in position with the angle of incidence of the aerofoil, and it is this changing of position as the aerofoil changes its angle of incidence, or, what is the same thing, as the air stream changes its direction, which makes the problem of keeping an aeroplane stable, under all conditions of flight, difficult.

The pressure on an aeroplane wing during flight varies, too, from the very state of the atmosphere. It decreases with height, for example, as the air is less dense the higher we go, and there actually comes a point when the pressure on the wings is only just sufficient to support the aeroplane. The height for any particular aeroplane is known as the ceiling, and when it is said that an aeroplane has a ceiling of 35,000 feet, it means that it can never climb beyond that height. The presence of water in the air, too, lessens the pressure on the aerofoil, while changes of temperature, gusts, and up and down currents all cause pressure changes over the surfaces of the aerofoil, changes which happen so quickly that it requires a skilled pilot to keep his craft on a steady keel.

We have now come to the general conclusion that owing to the curious shape of an aerofoil it has a much greater maximum lift in proportion to its resistance than a flat surface has. This L/D ratio, as it is called, varying, as it does, with the particular shape of the aerofoil as well as from other causes, makes the choice of an aerofoil for an aeroplane one requiring great judgment. Some aerofoils have a very high lift at moderate angles of incidence, and this type of aerofoil is useful as a weight-carrying machine. But such aerofoils have also a high resistance, and are not much good for an aeroplane which is required for speed. An aerofoil is chosen for fast machines which may not have a very high lift coefficient, but which will have a good L/D ratio. That is, the resistance will be low.

Taken generally, alteration in the maximum camber of an aerofoil affects its lift and its drag. The L/D ratio is usually highest when the maximum camber is about one-twentieth of the distance of the chord from the leading edge, and the lift is a maximum (apart from any consideration of a drag) when the maximum camber is about one-twelfth of the distance of the chord from the leading edge. The best type of aerofoil for an aeroplane wing falls in between. But these figures must not be taken as final as a considerable amount of research is still in progress in an attempt to find the best wing section, and certain forms of wings—as the Handley Page Slotted Wing—gives much better results in many ways than an ordinary cambered wing does. It is an alteration in the top curve of an aeroplane which has the greatest effect, an alteration in the bottom curve having very little effect. The best place for the maximum depth of an aerofoil is found

to be about one-third of the chord from the leading edge. In practice this position is usually put a little farther back, as wings with the maximum depth exactly at one-third of the chord are often found to be unstable.

If the drag or resistance of the wings were the only resistance that had to be considered when an aeroplane was flying the problem of flight would not be such a difficult one to solve.

Unfortunately there enters into the problem the resistance of all other parts of the machine, that of the landing chassis, the fuselage, the bracing wires and struts, and so on, and unless these are carefully designed the total resistance of the aeroplane may be so great that it will not fly. The resistance or drag of the wings or any other lifting surfaces on an aeroplane is often referred to as the active drag, and the the resistance of the non-lifting surfaces as the passive drag.

In order to make the drag or resistance of struts and wires and similar parts as low as possible they are streamlined in shape. Fig. 6 shows a streamline

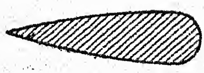


FIG. 6.

shape. Such a shape offers much less resistance to the flow of air past it than does a circular shape or a square shape. The eddy currents set up at the back of it are far less turbulent. The fitting of proper steamline fairings to struts on a machine, using

streamline wires and so on, will add many miles an hour to the speed of a machine, due to the lesser resistance offered. Since resistance increases as the square of the speed it is obviously of the greatest importance to cut down every possible form of resistance in a machine which is intended to fly fast.

We are now in a position to consider a little more closely how an aeroplane flies. Fig. 7 shows an aeroplane with all the parts named for convenience of reference in what follows. Many of these parts will also be explained further in the course of the description of the way an aeroplane flies. In turn it will be considered how an aeroplane gets off the ground, climbs, flies horizontally, glides downwards and lands, and also carries out certain simple manœuvres, as turning, looping and so on.

There are four controlling units on an aeroplane: (1) the engine; (2) the elevators; (3) the rudder; and (4) the ailerons or wing flaps. The engine controls the height at which the aroplane flies, the rudder and ailerons allow the aeroplane to be correctly banked and turned, while the elevators control the speed of the aeroplane.

To understand these points fully, and to understand the movements of an aeroplane in the air, a slight outline must be given of the forces acting on the aeroplane as a whole. When an aeroplane is flying level, it is clear that the total lift is exactly equal to the total weight of the aeroplane and all that is in it. It it were not, then the aeroplane would rise or fall according as its weight is less or greater than the total lift. The horse-power developed by the engine to fly at a given speed must be just great enough to overcome the resistance of the machine as a whole

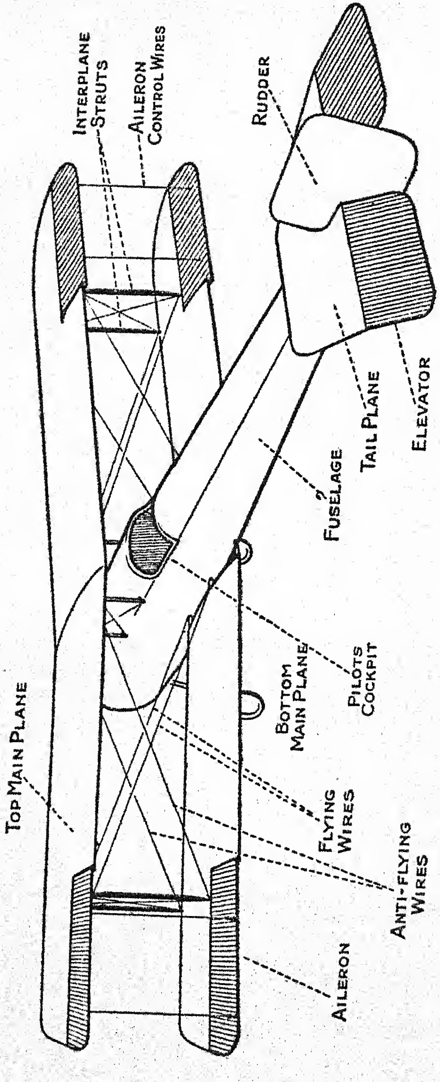

Interplane Struts
Aileron Control Wires
Rudder
Elevator
Tail Plane
Fuselage
Pilots Cockpit
Bottom Main Plane
Top Main Plane
Flying Wires
Anti-Flying Wires
Aileron

Fig. 7.

when flying at that speed. Naturally, the smaller the total resistance at a given speed the smaller is the horse-power required to overcome it.

Suppose the speed at which the aeroplane is flying horizontally is V miles per hour, and the angle of incidence of the main planes is L. Then the forces acting on the aeroplane are the lift acting vertically upwards through the centre of pressure of the wings and the weight acting vertically downwards through the centre of gravity of the aeroplane; the drag or resistance, acting horizontally in the opposite direction to the movement of the aeroplane and the thrust or pull of the propeller (driven by the engine) acting horizontally in the direction in which the aeroplane is

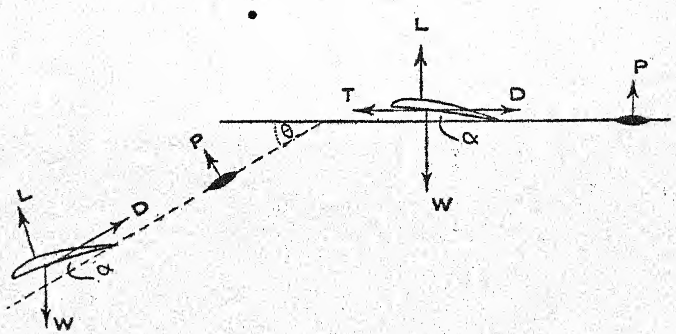


FIG. 8.

moving; and a force on the tail plane acting vertically. Fig. 8 shows these forces diagrammatically.

L is the lift.
W the weight.
T the thrust of the engine.
D the drag or resistance.

P the force on the tail to preserve balance since the weight of the machine and the lift are not acting through the same point.

Suppose now the engine is cut off. Then the speed of the aeroplane immediately lessens, and the lift of the wings is lessened in consequence. That is the lift is now less than the weight of the aeroplane, so that the latter begins to glide downwards. If the aeroplane is stable, the main planes keep the same angles of incidence towards its new flight path, the gliding path, as they did to the horizontal flight path when it was flying horizontally. The gliding path is shown dotted in the figure, and the angle of incidence of the wings as the angle L. There is a different angle at which the aeroplane will glide down for every speed at which it is flying horizontally when the engine is cut off. There is a best angle of glide, and in a modern aeroplane this corresponds to a gliding path of about one in eight or ten.

We can now see why the engine is the chief factor for controlling the height of an aeroplane. If the machine is flying level with the engine throttled down, then the power is just sufficient to keep it flying horizontally. But if the engine is now opened out there is an excess of power over that required and the machine begins to climb. If it is wished to alter the speed of flight horizontally, then the angle of incidence of the main planes must be altered, and to do this the tail elevators (movable flaps on the tail plane) are moved so that the tail offers more or less resistance in the direction of motion, and so swings the aeroplane round its centre of gravity into the new attitude. When this new attitude is reached there is a greater or less resistance of the wings according to

the way the angle of incidence has been altered, and so the horse-power of the engine will have to be adjusted in accordance with this increase or decrease or resistance. If it is not, the aeroplane will fall or climb.

The elevators and the engine control between them the speed and climb of the aeroplane.

On the main planes are small movable flaps, known generally as ailerons. These movable flaps are usually placed at the back of the tips of the wings, and form part of the surfaces of the wings. These ailerons are used to make the aeroplane bank correctly when on a turn, or to keep lateral control.

What happens is this. The pilot, by means of his controls, is able to depress the ailerons on one wing tip and raise those on the other wing tip at the same time. This increases the lifting force on one side of the aeroplane and decreases it on the other, so that the aeroplane tilts on one side, *i.e.* banks. The ailerons are used in conjuction with the rudder when it is required to turn, so that the aeroplane is banked in the air correctly for its turn. If it were not banked correctly when turning, it would side-slip, just as a cyclist does when turning a corner too fast. In the case of the cyclist this usually means a spill, too, as the road does not allow his wheels to side-slip uniformly until he can recover his equilibrium. In the case of the aeroplane, if it is too near the ground the machine crashes before the pilot can regain control and put the machine on the correct bank.

The ailerons, rudder and elevators are controlled by the pilot. A joy stick or control column or a wheel control is used to control the ailerons; and the elevators, and a rudder bar or pedals worked by the feet to

control the rudder. Where a control column is used, it is usually vertical when the controls are central. The ailerons and elevators are connected to the control column by cables passing over pulleys. A movement of the control column to the right or left actuates the ailerons, and forward or backward the elevators. When the control column is pushed forward the elevators are depressed and the aeroplane tries to dive. Pulling the control column back raises the elevators, and the aeroplane loses speed and tends to stall, that is, it either falls bodily through loss of flying speed, or slides backwards, the speed of flight lessening, so that the lift of the wings is not sufficient to support the aeroplane.

The rudder bar or pedals are so arranged that when the right end of the bar or the right pedal is pressed the aeroplane turns to the right, and conversely. A movement of the control stick to the right causes the ailerons to be adjusted for a right-hand turn, so that in this way the movements of the control stick and the rudder bar follow one another. With a wheel control the ailerons are usually controlled by the turning of the wheel, and the wheel column is moved forward or backward to control the elevators.

When the pilot wishes to rise from the ground he first of all starts his engine, and so sets the propeller moving round to provide the necessary thrust or pull to drive the aeroplane forward. This pull is sufficient to make the aeroplane move rapidly across the ground. If there is any wind blowing the pilot turns into it, that is, against it, and adds the speed of the wind as it were to that of the aeroplane, so that he can obtain flying speed with as short a run on the ground as possible. There is a minimum flying speed at which a

particular aeroplane will remain in the air, and the relative speed of flow of the air past the wings must reach at least this minimum speed before the aeroplane will begin to rise.

As speed is gained while the aeroplane is taxying over the ground the tail of the machine rises and the aeroplane taxies with the top rail of the fuselage practically horizontal. The tail of the machine is made to rise by the pilot depressing the elevators. When the pilot knows, by the instruments on his dash board, that flying speed has been reached, he pulls his control stick back, the tail drops, and the main planes take up a large angle of incidence to the flight path. This gives sufficient lift to raise the aeroplane into the air.

The machine climbs, as explained in a previous paragraph, the angle of incidence of the main planes to the flight path being controlled by the elevators, so that only part of the power of the engine is required to keep up the forward speed, the remainder being utilised for climbing.

The aeroplane is now in the air flying horizontally, and the pilot wishes to circle round the aerodrome, climbing steadily so as to gain height over the aerodrome before beginning his journey. Suppose he is circling round to the left and climbing at the same time. He pulls his joy stick over to the left and also back towards him, and presses with his left foot on the rudder bar, and opens out his engine as much as necessary. If all these things are correctly done, so that the aeroplane is properly banked for the turn the pilot is giving it with the rudder, the machine will continue to circle round and climb. When he has reached the height he desires the machine is brought

on an even heel and the engine throttled down to the appropriate speed the aeroplane is to fly at, a speed determined by the angle of incidence of the main planes as controlled by the elevators.

Once the aeroplane is set upon its course then, provided the weather is fine, there is little for the pilot to do except to keep his eyes on the instrument board and make such small adjustments to the controls as one has to do when driving a car. When the machine reaches its destination it usually circles round and glides down, either with the engine throttled down or cut off altogether. In actual landing the aeroplane is brought into the wind when possible, so that its speed over the ground shall be as low as possible and the speed of the air stream past the wings as high as possible. Close to the ground the elevators are raised by pulling back the control column, the tail drops, and the planes assume a comparatively large angle of incidence to the flight path of the aeroplane. The chassis wheels touch the ground, the machine slowly loses speed, the tail drops, and finally the aeroplane comes to rest.

The above, in main outline, is the why and wherefore of an aeroplane flying. It is only possible in a book of this description to give a general outline, as the mathematics and the theory of flight in all its details are very complicated. Exactly how air flows past any object, for example, is not yet known, and it is not possible to calculate the resistance to air flow of any object of any shape, though a fairly close approximation may be made.

A short description of the various special manœuvres which an aeroplane can carry out is now given. These manœuvres are not required for normal flying, but are

necessary for military machines, when the ability of the pilot to handle his machine quickly and in any direction is very important in air fighting.

The first manœuvre is looping. When an aeroplane loops, it, in effect, travels through a more or less elliptical vertical flight path as shown in Fig. 9. The

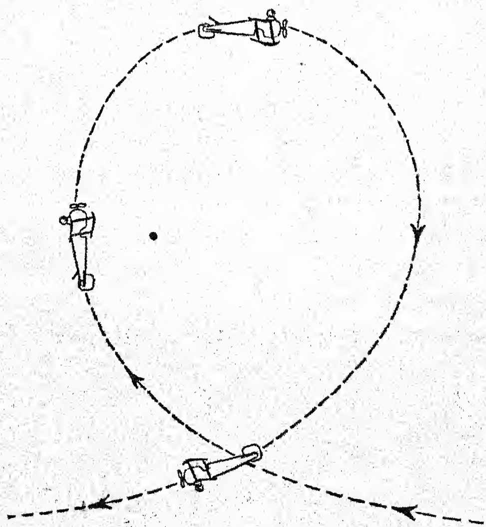


FIG. 9.

aeroplane is dived or flown at such a speed that when the joy stick is pulled right back the machine has just sufficient impetus to carry it over the top of the loop. This manœuvre may be very dangerous indeed, the dangerous part occurring at the entry of the loop. If an attempt is made to turn the aeroplane too quickly,

that is, if the entry into the vertical flight path is too sudden, the machine will break in the air. It is like trying to turn a motor car sharply when it is moving at high speed. If it does not actually turn over or skid, the chances are the tyres will be torn off, or some of the mechanism will be broken. A very heavy strain is placed upon an aeroplane when it is suddenly pulled out of a nose dive to loop, and so the entry into a loop should be as gradual as possible.

In a nose dive, which is generally the preliminary manœuvre for a loop, the nose of the aeroplane is pointed vertically downwards, and the aeroplane dives towards the earth in a more or less vertical path. Very high speeds can be reached in such a position, and high speeds always mean that there are heavy strains on some parts of the structure, and, as a matter of fact, these strains have to be allowed for when designing the machine.

When an aeroplane is put into a spin, it is descending and rotating round a vertical axis. To make an aeroplane spin, the pilot first of all stalls it, that is to say, he pulls the control column back so as to give the wings such a large angle of incidence to the flight path that it loses the speed necessary for flight. He then applies the rudder, which gives the necessary twist to start the spinning. The speed at which a machine spins depends upon its type, some only spinning three or four times in 1000 feet, while others will spin as many as nine times in the same distance. A spinning nose dive may be perfectly safe if it is stable. In that case the speed of the aeroplane is constant, and the rate at which it is rotating is also constant. If the aeroplane keeps gathering speed in a spin, then the spin is an unstable one, and extremely dangerous. It

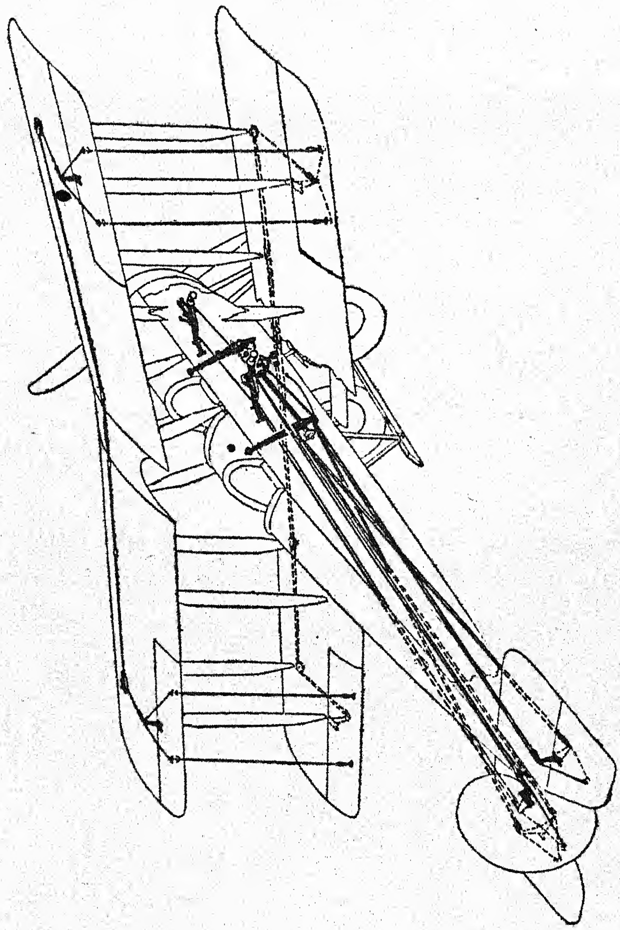


Fig. 10.

may be then that the pilot will be quite unable to get out of the manœuvre and the aeroplane will crash to the ground. There are, of course, various other ways of spinning a machine besides first stalling it. It can be made to spin in a nose dive, for example.

CHAPTER IV

SOME FAMOUS FLIGHTS

MAN had no sooner learnt to fly than he became more daring than the birds themselves. Since those wonderful exhibition flights of Wilbur Wright in France in 1908 there have been many thrilling flights.

In 1909 the *Daily Mail* offered a prize of £1000 for the first pilot to cross the English Channel in an aeroplane. A flight of twenty to twenty-five miles! The distance had been exceeded over and over again in France by Wilbur Wright and others, but all these flights had been made over land, within easy distance of the ground, and with plenty of people about. To fly over the Channel was a very different story. It would mean that for the first time a human being was up in the sky above on a heavier-than-air machine, with the knowledge that if his engine failed he would probably be driven to diving into the water and being drowned. And in those days aeroplane engines were not so reliable as they are now!

It required a supreme courage to battle with the unknown air currents between England and France in those early days. As far as any man knew at that time, he might be flying to almost certain death, and yet immediately the announcement of the prize was made half a dozen stated that they would attempt to win it during the course of the next few weeks.

Public excitement rose to fever heat, especially in England, as reports began to appear in the newspapers of the preparations which were being made by Hubert Latham, Louis Bleriot and others who had already

inscribed their names on the aeronautical roll of fame. All England felt one thing: The crossing of the Channel would be an epoch-making event, for it would mean that, in a sense, the "right little, tight little island" was an island no more, that she could be invaded from the air as easily as continental countries could walk into one another's territories. And what changes that ability to cross another country's frontiers thousands of feet up in the sky would make, were only dimly foreseen, and are not completely visualized yet. But the crossing of the Channel was felt deep down in every one's mind to be the beginning of some vast change, and so every day news was eagerly awaited.

There were two men who were to make themselves famous over this Channel flight. One was Hubert Latham and the other Louis Blēriot. Latham was the pilot who, later in the year, made spectators gasp with sheer admiration for his daring as he battled in a fluctuating 30-mile an hour wind at Blackpool, a man of wealth who had no occasion to risk his life, but flew for the sheer thrill of it. Twice he had travelled round the world before he was thirty, had hunted big game in Africa, and had leapt into fame as an aviator. He was killed in 1912 while hunting big game in the Congo.

Louis Bleriot was one of the earliest of French pioneers of the air. He was closely associated with Voisin in 1904 and 1905. As early as 1900 Bleriot had built a flapping wing model, in 1907 he carried out a series of flights on a monoplane of his own design, and in 1908 he made a daring cross-country flight. The machine he entered for the Channel flight was the eleventh machine he had built.

It is interesting to note that Bleriot's monoplane

weighed 660 lbs. all up, including the weight of the pilot and petrol for a three hours' flight. Its speed was 37 miles an hour, and the engine was a three-cylinder 25 horse-power Anzani. It was a monoplane with a lifting surface of 150 square feet, and was constructed chiefly of oak and poplar, piano wires being used for bracing.

Both men worked feverishly at their machines to have the honour of being the first to fly across the Channel. Both men determined to start from the French side. The race between the two was curiously reminiscent of the race for premier honours in 1919 between H. G. Hawker and Captain John Alcock in the great Atlantic flight. In both cases the man to start first was defeated after an attempt which stirred the imagination of the world.

Hubert Latham had a small hangar at Sandgate, and on Monday the 19th of July, a little after six 'clock in the morning, he rose in his Antoinette monoplane and headed out to sea, for the English coast. But he was only six to eight miles from his native land when his engine began to misfire, and Latham was forced to descend into the water. Luckily the aeroplane kept afloat, and Latham was found sitting smoking a cigarette when he was rescued by a tug-boat. It was a splendid failure and set the world talking.

And then excitement was raised to fever pitch when it was announced that Louis Bleriot was almost ready, and any day the newspapers might announce that the Channel had been conquered. Bleriot was badly hurt in an explosion of petrol, and when on Sunday, 25th July 1909, six days after Latham's failure, he decided to attempt the great flight, he hobbled out to his machine on crutches ! Just after four o'clock he rose

in his machine and flew round for a few minutes to test it. The engine was running perfectly, a light breeze was blowing, everything was propitious, and Bleriot landed.

"I am starting for England in ten minutes," he announced to his mechanic.

At half-past four the engine was started, and five minutes later the intrepid Frenchman was a hundred feet in the air, the nose of his machine pointing to Dover. Forty minutes later he had landed on the English coast. For most of that time he had been flying without any means of knowing whether he was flying straight out to sea, or whether he was steering straight for England. Any change of wind would have blown him out of his course and he would in all probability have been lost. But the wind held steady, and at twelve minutes past five Louis Bleriot landed on North Fall Meadow, just behind Dover Castle.

The Channel had been flown.

He had partly lost his way in coming over, and he did not land on the spot for which he aimed; so the only actual witness of his arrival was appropriately enough a British policeman, who happened to be on duty near the spot where Bleriot landed. His alighting place was afterwards marked by a stone aeroplane, a historic monument.

Two days later Hubert Latham, undeterred by his previous experience, set out at six o'clock in the evening in an attempt to emulate the feat of his successful rival. Torpedo boats lined the Channel in case of accidents. Again Latham's luck was out. A mile and a half from Dover his engine once more failed and he was forced to drop into the water, to be picked up by the steam pinnace of a British warship.

The English Channel was not to be crossed again until the following year. In the same year C. S. Rolls flew from Dover to Barraques and back again, the first airman to do the double journey without landing. Now the Channel is flown regularly every day, and its crossing has become such a commonplace that it attracts no more attention than the passage of the cross-Channel steamers.

The great event of 1910 was the winning of the £10,000 prize offered by the *Daily Mail* for a flight from London to Manchester. The flight took place on 27th and 28th April, and resolved itself into a race between a Frenchman, Louis Paulhan, and an Englishman, Claude Grahame-White. Grahame-White had already made an attempt a few days earlier, getting as far as Lichfield, where he was forced to descend with engine trouble. He returned immediately to London for repairs, racing against time, as Paulhan had already entered for the flight and was assembling his machine.

Both machines were ready at the same time, but about five o'clock in the afternoon the weather appeared to be unfavourable, and Grahame-White went away to rest, in order to be as fresh and fit as possible the following day. Paulhan, knowing the value of every minute, determined to take the risk of flying. That evening he rose and flew to Lichfield, while his rival slept. That flight must always be considered one of the greatest of pioneer flights, for Paulhan flew in windy weather over a strange country and in the dark part of the time. He made a magnificent landing in the dark, however, in a small field near Lichfield, and at four o'clock the following morning was off again. At half-past five he had landed just outside Manchester.

Grahame-White made a gallant attempt to overtake his successful rival. He was awakened an hour after the news was known that Paulhan had started, and at half-past six he was in the air, though darkness was already setting in. At eight o'clock he came down at Roade, 60 miles from London, and at three o'clock he was off once more, but was forced to land at Polesworth, 107 miles from London, with engine trouble.

Flying the Atlantic

In 1913 the *Daily Mail* offered the huge prize of £10,000 for the first pilot to fly the Atlantic in less than 72 hours in a heavier-than-air machine. At the time many people sarcastically remarked that the prize might just as well have been ten million pounds for all the chance it had of being won. It is difficult to realize how sceptical even most of the scientific men were then of the possibilities of human flight. But there were aeroplane enthusiasts who were daring enough to predict that the prize would be won in ten years from the date of its announcement. As a matter of fact but six years passed before the *Daily Mail* was called upon to pay over the amount they had offered.

The problem facing the aeroplane designer was a formidable one. He had to design an aeroplane which would fly at least 1800 miles, which would keep in the air for eighteen to twenty hours, and which would have an engine that was absolutely reliable. Moreover, he was faced with weather conditions of which he had very little knowledge. He might start from Canada or Newfoundland in fine weather and encounter a storm over mid-Atlantic which he could not weather. He might

meet with conditions of perishing cold, which would seriously effect the working of his engine. Over the Grand Banks there was often a fog extending up to 2000 feet in height, and from Newfoundland to the Grand Banks he might have to fly over an ice area which would make forced landing conditions on the water perilous. The weather conditions in mid-Atlantic were very little known and violent weather changes were not uncommon.

The flight of the Atlantic required not only skill on the part of the designers of the aeroplane and its engine, but it required skill and a high order of courage on the part of its pilot and navigator. Both knew that they were flying into the unknown with unknown prospects of ever seeing land again. And yet when the time came there came with it the men, prepared to attempt what surely must have been one of the most hazardous enterprises in the history of man.

The Great Atlantic Failure

Some failures are far more inspiring than if they had been successes. Such a failure was that of Commander Scott to reach the South Pole, a failure which was in some ways far more glorious than success would have been. And another such failure was that of Harry Hawker and Commander Grieve to fly the Atlantic.

Harry Hawker was an Australian. Originally a motor mechanic—a super motor mechanic, indeed, for he had an uncanny knack of handling a motor engine which has rarely been equalled—he came to England and became an employee of Mr T. O. M. Sopwith, one of the pioneers of flying. Mr Sopwith had at that time a flying school, and when his star

mechanic expressed a strong desire to fly he allowed him to do so. The first time a pupil went up it was usually for anything less than ten minutes. But the first time Hawker rose in the air he was so fascinated by his new sensations that he stopped up there an hour. After that first flight nothing would content him but that he should become an expert flyer. That was in 1912. When he was killed in 1921 owing to his aeroplane catching fire, he had become one of the best known airmen in the world, so much so that seasoned pilots would turn out to watch him fly when they heard that Hawker was up. In nine brief years, five of which were war years when opportunities for individual records were small, he had accomplished feats which would have satisfied most men for a lifetime.

Hawker was such a fine airman for one reason above all others, and that was that he was never happy unless he was flying. It used to be said that it was fatal for him to be near an aeroplane, for he would not be content until he was up in it.

Commander Grieve, the navigator of the Sopwith machine, and Hawker arrived at Newfoundland on 28th March 1919. The presence of other competitors, all eager to have the honour of being the first to fly the Atlantic, keyed everyone up to get their machines into condition as soon as possible. The day before they left England Hawker and Grieve had carried out a test flight of 1800 miles to prove to their own satisfaction that their aeroplane could fly the distance.

They had decided if possible to start from St Johns, Newfoundland, on 16th April, a little over a fortnight after their arrival. That night there would be a full moon, which was advantageous for their flying. They hoped to land in Fermoy, in County Cork, Ireland,

after being in the air eighteen to nineteen hours continuously.

On 10th April Hawker and Grieve carried out a test flight, and hoped to make the great attempt two days later. But luck was against them. Their wireless set went wrong and the weather was unpropitious. Day by day the flight was postponed, and day by day rival competitors were getting nearer being ready to start, making the tension of waiting almost unbearable.

The Sopwith machine, christened the *Atlantic*, was a biplane with a 350 horse-power Rolls-Royce engine. When fully loaded at the start the machine weighed 6150 lbs., nearly three tons. This weight included 350 gallons of petrol, enough for flying for 22 hours. It was estimated that an average speed of 100 miles an hour would be reached so that, all going well, the Atlantic should be crossed in about cighteen hours. The construction of the fusalage of the machine was ingenious. Its upper half was really a boat fitted on upside down for streamlining. Hawker and Grieve relied upon this boat to keep them afloat in case it was found necessary to land in mid-ocean. Both the men were provided with special safety suits which would enable them to keep afloat for a long time.

The delay due to the weather enabled Raynham, who had arrived after Hawker, to get his machine, a Martinsyde, ready for the flight, and both men, old friends and old rivals, were waiting, waiting, waiting for the skies to clear. And perhaps that waiting was the most nerve-testing period of all. That the strain of it was affecting people all over the world is shown by the fact that the waiting pilots received a number of cablegrams begging them to start, as the suspense was becoming unbearable!

On 6th May 1919, three American seaplanes left Newfoundland to fly the Atlantic *via* the Azores. Both Hawker and Raynham felt keenly the possibilities that the honour of being the first to cross the ocean were slipping from Great Britain. Bad weather reports prevented them from flying, however, and they could not take the risks the Americans were taking. For one thing, the Americans were flying farther south, and for another, the route was being patrolled by warships, so that in case of a forced descent the chances were greatly in favour of the airmen being saved. With Hawker and Raynham, however, success was almost imperative. Failure meant almost certain death, despite the precautions they had taken to keep afloat.

On the morning of the 18th of May news was received that the weather was favourable for the great attempt. At 3.15 p.m. that afternoon Harry Hawker and Commander Grieve gave the signal for the chocks to be pulled away beneath the wheels.

The great flight had started.

Immediately the news was cabled all over the world, and millions of people waited anxiously hour by hour for news of the two men, alone in the air, somewhere above the Atlantic.

The following day the newspapers had only one great black headline—Hawker Missing.

Day followed day with no further news. Weather reports from the Atlantic had reported bad storms in mid-ocean but a few hours after the two had started. "All hope has now been abandoned for the safety of the Atlantic airmen," was the tenor of the news at the end of the week, and most of the newspapers printed long obituary notices of the two men. That all hope had indeed been abandoned is perhaps best shown by

the following telegram to Mrs Hawker from the King:—

"The King, fearing the worst must now be realized regarding the fate of your husband, wishes to express his deep sympathy and that of the Queen in your sudden and tragic sorrow. His Majesty feels that the nation lost one of its most able and daring pilots, who sacrificed his life for the fame and honour of British flying."

It was on Sunday, 8th May, that Hawker and Grieve flew into the Unknown. It was on Sunday, 15th May, exactly one week later, that they came back from it. On that morning a small steamer, the *Mary*, came in sight of the Butt of Lewis, Scotland. Her siren was blowing, and she signalled to the coastguards that she had important news to communicate. Then came the historic signal.

"Saved hands, Sop. aeroplane."

The coastguard signalled back.

"Is it Hawker?"

"Yes," ran up the signal flags of the *Mary*.

The news came like a thunderclap. A British destroyer was immediately sent from Scapa Flow to take the two airmen on board and to hear their stories. That night they spent on board Admiral Freemantle's flagship, H.M.S. *Revenge*, and on Monday morning they landed at Thurso, to take the train to London. The overwhelming feelings occasioned by their return from the very gates of death may perhaps be best expressed in the words of the Provost of Thurso:

"Mr Hawker," he said "in the name of the people of Thurso I offer you and Commander Mackenzie Grieve a welcome, not only to Thurso, but to the shores of Britain. Throughout the length and breadth of the

land, and of every land, to-day the news of your safe deliverance is ringing, and hearts everywhere are rejoicing. It is true that you have not achieved what you so gallantly set out for, but to-day you need not worry over that, because you have indeed achieved great things. The names of Hawker and Grieve will live for ever in the annals of the Atlantic flight. You have brought a new lustre to the daring, the endurance, and the intrepid spirit of our race. Your countrymen greet you warmly and proudly as heroic pioneers and sportsmen. From the moment of your departure from St Johns the world has been on tension for news of you; expectation gave way to anxiety, and then anxiety to gloom, but happily all fears and forebodings to-day are dispelled. The world-wide joy over your pluck and safety is so great because the sense of relief is so great. It was at this landing-stage that Lord Kitchener said farewell to the land he loved, and now we shall also know it and mark it as the place of wonderful welcome to the brave sons of Empire."

It was a wonderful story of a glorious failure Hawker and his companion had to tell. Ten minutes after losing sight of land the aeroplane ran into the thick fog of the Newfoundland Banks and lost sight of the sea. Grieve was working out the position of the aeroplane by the sun and stars every half hour, and he reported to Hawker that the machine was drifting to the south out of her course. Contrary to all they expected a strong north wind was blowing, making the machine drift away from its line of flight unless corrected for. After flying four hours, during which they had only one glimpse of the sea, the weather became very bad. Heavy black clouds were rolling up from all sides, the wind increased, and stinging rain

squalls beat into their faces. The very elements themselves were fighting against success.

The two had been flying five and a half hours under such conditions, and were now some five hundred miles out to sea, when Hawker began to notice that the radiator of his engine was getting hot. Something was choking the pipes, interfering with the proper circulation. He knew at once that if he could not keep the radiator cool the end of the flight was not far off. The terrible weather they were now encountering made it impossible to see far ahead, and the prospects of being rescued if they fell into the sea were remote. Moreover Grieve reported that the machine was many miles off the steamship route, which made their prospects of saving their lives still less.

Flying at 10,000 feet Hawker was still not above the huge storm clouds, and he dared not climb higher, as every time he attempted to do so the water in the radiator began to boil. Time and time again he glided down and cut off the engine to allow the water to cool. During a break in the clouds Grieve was able to get a sight of the Pole Star, and he found that the machine had been blown by the gale 150 miles from her course.

Once, in diving down, the engine refused to start until the machine was actually within a few feet of the water, and both men were preparing to face an icy plunge into the sea. It was a little later, when the sun began to rise, and after he had been flying for nine hours, that Hawker decided that the attempt was doomed to failure. The radiator was overheating, the precious water boiling away, and the constant fight against the north wind had consumed more petrol than was expected. In fact, half the petrol had gone and the aeroplane wasn't half-way over. He decided to

fly backwards and forwards across his course as long as his machine would hold out, in the hope of sighting a vessel of some kind.

The weather was thick and misty, making it difficult to see, and with the aeroplane pitching and rolling in the gale the chances of success seemed small. Then, suddenly, the men saw a small ship on their left, close to them, the *Mary*. They were indeed almost over it before they saw it, so bad was the visibility. Grieve promptly fired three Very lights as a distress signal, and when they saw that those on the ship had seen them Hawker glided down and landed on the water. The sea was very rough, and it was over an hour and a half before the two could be rescued, though only a couple of hundred yards separated the aeroplane and the *Mary*. It was largely due to the fuselage boat they carried and launched, that the two airmen were able to keep afloat until rescued.

The *Mary* had no wireless on board and so could not communicate the wonderful news to a waiting world. She was bound from New Mexico to Perth, crossing the Atlantic steamship route, so that she did not meet any ship with wireless with which she could communicate.

How near they were to disaster may be realized when it is stated that after landing in the sea Hawker found that he had not got a single drop of water left in the radiator.

Both men were awarded the Royal Air Force Cross, a distinction all the more remarkable in that its award is confined normally to those serving in the Royal Air Force. But for once red tape was broken through effectively, and few can say that Hawker and Grieve did not deserve the cross awarded for "acts of gallantry in the air."

The total distance flown over the Atlantic before the *Mary* was sighted was just over 1000 miles.

The Atlantic Success

In the summer of 1917 Vickers Ltd. were asked to design a heavy bombing machine, which was given the type name of "Vimy." In November 1917, this machine carried out successful flights with two 200 horse-power "Hispano-Suiza" engines. It was calculated that if this machine was equipped with two 350 horse-power "Eagle" Mark VIII Rolls-Royce engines, it would be capable of flying a greater distance than that between St Johns, Newfoundland, and the west coast of Ireland. A scheme was accordingly prepared and submitted to the Air Ministry on 18th April 1918 to do this flight, but was not undertaken owing to the war. In April 1919 a standard Vickers "Vimy" bomber had the following alterations from the standard aeroplane to fit it for the Atlantic flight :—

1. No armament.
2. Crew reduced from three to two.
3. Petrol tank capacity increased to 865 galls.
Oil tank capacity increased to 50 galls. } Approx. four tons.
4. Instruments and petrol pipe system adapted for extra tanks.

This amount of fuel was sufficient for a range of 2440 miles, or a margin of 30 per cent. for the Atlantic flight in a calm.

The aeroplane was erected and flown by the end of April; shipped from England for Newfoundland on

the 4th May, and returned to Ireland on the 15th June.

The dimensions of the machine were as follows :—

Span	67 ft.
Length	42 ft. 8 in.
Height	15 ft. 3 in.
Gap	10 ft. 0 in.
Chord (or width of Wings) .	10 ft. 6 in.

The proportion of the load carried to the weight of the aeroplane fully loaded was 53 per cent.

The following is the description by the pilot, Capt. Sir John Alcock, K.B.E., D.S.C., of the successful attempt which had so gloriously failed in the case of Hawker and Grieve.

"On 9th June, our first trial flight was carried out. During this flight the machine behaved splendidly. However, the wireless installation gave slight trouble. I landed at a place known as Munday's Pond, where an aerodrome had previously been prepared under very adverse circumstances, and after encountering great difficulties, such as blowing up rocks, removing walls, levelling small hills, and taking down fences, etc., obtained a clear run of 400 yards.

"The defects which appeared during the first trial flight having received attention, a second trial flight was made on Thursday, 12th June, when the aeroplane was then found to be quite in order. On Friday, 13th June, the tanks were filled up with petrol, lubricating oil, and water. My intention was to make an early start on the morning of Saturday, 14th June, but this was impossible owing to a strong cross wind. The engines were tested for the last time, and ran to perfection; the petrol tanks were then finally re-

plenished ready for the start. Later on during the day, weather conditions became more favourable. Brown and I then had our final meal before starting, seated under the wings of the aeroplane. At 5.13 p.m. (British summer time), we started on our eventful journey, having to 'take off' up a slight gradient with a little side wind, the narrowness of the ground preventing the start being made head to wind. The machine took off very easily, but I experienced some trouble in attaining sufficient height, so I had to fly down a valley which had a very steep range of hills on either side, this causing bad bumps, and a considerable amount of height was lost through the bumps. After some difficulty we eventually reached the end of the valley and, turning the machine head to wind, quickly climbed up to 1000 feet, and proceeded on our course. We rapidly passed over St Johns and directly over Cabot Hill, at a height of about 1200 feet; Brown then gave me my direction which was a S.E. course of 124° (magnetic). At the start visibility was very good, but the Newfoundland fog bank could be seen ahead, and we were soon flying between a bank of clouds and the fog. We did not see either the sea or sky for a period of seven hours with the exception of an occasional glimpse of both, in small patches. As the light failed worse conditions were encountered; clouds and fog became denser; eventually we were flying in the bank of the fog. Suddenly we struck a clear patch in the bank of clouds where Brown was able to check his position from a sight of the Pole star, Vega, and the moon. This lasted half an hour. However, later thick fog together with the bad bumps impeded him from holding his course. The machine then started to spin, caused through the air speed indicator failing

to register, probably due to the pitot tube which had been damaged, when the wireless generator propeller was blown away. (The wireless generator propeller shaft sheared ten minutes after the start.)

"The spin started at a height of 4000 feet. We rapidly lost height, and on coming out of the mist found ourselves very close to the water, at a dangerous angle. Upon seeing the horizon I was able to regain control and put the machine on its true course. Climbing again to 7000 feet through thick fog we saw the moon once or twice, but Brown was unable to obtain any readings. We continued to climb steadily, trying to get above the fog, and were still climbing at daybreak in large banks of clouds which we could not get above. This continued for about five or six hours; hail and sleet were encountered, which caused the radiator shutters to become jammed, also obscuring our petrol and sight gauge and choking up the pitot tube. We climbed steadily to 11,000 feet, hoping to get above the clouds and take further readings from the sun. At this height we saw the sun several times trying to force its way through the clouds, and Brown eventually succeeded in fixing up his position. After this we decided to descend, and almost reached the surface of the sea before obtaining clear visibility; here the wind was blowing very strongly from the south-west. To counteract this, Brown thought it advisable to steer a more south-westerly course, flying in this direction close to the water for about 40 minutes when we saw the two islands of Eeshal and Turbot, but we could not see the mainland owing to rain and low clouds. The mainland was not visible until we were practically over it, and then only the hills. In another 10 minutes the masts of Clifden wireless

station suddenly appeared; we circled round these firing Very signals, to which no reply was received. Whilst flying round looking for a suitable landing place, we passed over Clifden town, where more Very signals were fired, again without reply, and observing no suitable ground in that neighbourhood we returned to the wireless station, where I had spotted what appeared to be a suitable field, and decided to descend. On touching the ground, however, this field turned out to be a bog, and the machine was slightly damaged, but we were unhurt. The operators of the Marconi station immediately ran to our assistance, but had no idea who we were until informed; they received us with great enthusiasm and cheers. We were then invited to the Marconi station, where we received every kindness, and messages announcing our safe arrival in Ireland were sent broadcast throughout the world."

The time taken was 15 hours 57 minutes.

The amount of petrol remaining in tanks at the finish was sufficient for a further flight of approximately 800 miles.

The engines were undamaged, and, in fact, the whole machine was perfect at the time of landing.

The Trans-Atlantic "Vimy" aeroplane was presented to the British nation, and is now to be seen at the Science Museum in South Kensington.

Both Captain John Alcock and Lieutenant Whitten Brown were afterwards knighted by the King in recognition of their successful and historic flight. For 15 hours the two men had been completely out of touch with the world, fighting bad weather, and with but small hope of rescue if anything went wrong. But nothing did go wrong, and the greatest

flying feat up to that time was successfully accomplished.

The Flight to Australia

Shortly after the end of the Great War the Australian Government offered a prize of £10,000 for the first aeroplane manned by Australians to fly from England to Australia in a maximum time of 30 days, or 720 consecutive flying hours.

Even given the machine capable of flying such an immense distance it meant an organization on land which had to be more of the most thorough description if the flight stood any chances of being successful. On 12th October 1919, Messrs Vickers entered the Vickers Vimy for the flight, and Captain Ross Smith, his brother Keith Smith, and Sergeants Bennett and Shiers, all Australians, and all experienced flyers, were chosen to undertake the flight.

The route decided upon was London, Paris, Rome, Cairo, Bagdad, Karachi, Delhi, Calcutta, Rangoon, Bangkok, Singapore, East Indies, Port Darwin, Sydney, Melbourne, Adelaide. The distance from London to Port Darwin, the first point of arrival in Australia, was 11,060 miles, and the total distance to Adelaide, 14,350 miles. It was a giant undertaking, but Keith Smith laid the foundation stone for its success by first of all surveying all the route except that from London to Cairo, which was too well-known to need a careful survey.

The worst part of the journey was undoubtedly that from Calcutta to Australia. Nowhere were there proper landing grounds for the giant twin-engined machine being used, but everywhere there were dense

jungles, and it was necessary to prepare a landing ground at Bima in the Dutch East Indies. At other places *en route*, after Calcutta, the pilot relied chiefly upon landing on race courses. At all likely stopping places it was arranged that fresh supplies of petrol and oil should be stored in readiness for the flyers.

The Vickers Vimy used was the same type of machine that had already covered itself with glory by crossing the Atlantic in a non-stop flight. It had two Rolls-Royce Eagle VIII engines, each of which developed 360 horse-power, and the total weight of the machine fully loaded was six and a half tons. Enough petrol could be carried on board for a 13 hours flight at 80 miles an hour, a distance of 1040 miles. This allowed ample margin for flying between landing places, none of which was 1000 miles apart. A number of spares were carried, as it was certain that if the machine broke down on the way it would be impossible to send spare parts out from England in time to complete the flight in the scheduled thirty days.

"Previously I had been from England to Australia several times by mail steamer, and on each occasion I had embarked either at Tilbury or Marseilles and in due course reached Adelaide, and thought very little about the journey," wrote Ross Smith afterward describing his flight, "but here was something vastly different.

"This time we had an aeroplane at Brooklands aerodrome and somewhere away on the other side of the world was Australia. We were going to climb up into the air and *fly* through thousands of miles of space to our own home! It was to be a great adventure—this skimming through 'unknown skies,' over strange lands, and vast spaces of ocean. Furthermore, we

were attempting something which had never been done, and so it was no wonder that we were elated at the prospect and went about our work with eagerness and light hearts.

"I knew that the physical and nervous strain of long flying hours day after day would be great, so we all went into training and generally took care of ourselves. At night we would work on the maps, plotting out the course and studying the prominent landmarks, and so long before we left England we had practically visualized most of the country that we were to fly over."

As the machine had to fly over foreign territory the International Air Convention required that it should carry the distinctive aeroplane lettering all such machines must carry. The Air Ministry allotted the letters G—E A O U for the machine, which the pilot and his companions interpreted as meaning "God 'Elp All Of Us!"

On 12th November 1919, the Vimy rose from the flying ground at Hounslow, and after circling round for ten minutes to ensure that everything was in flying trim, the machine started on her great-hearted aerial voyage. Ross Smith acted as the pilot and his brother Keith as the navigator.

Almost as soon as the machine left England it found itself in difficulties. Over the coast of France was an immense wall of snowclouds, several thousands of feet in height. Ross Smith tried to fly beneath them, and in a few minutes the machine was covered with snow and the goggles of the pilot were a mass of ice particles. Quickly he turned his machine round, and coming out again into the sunshine, decided to climb over the snow wall. It was not until he had

reached an altitude of over 9000 feet that he was able to clear the storm. Below him France was being covered with a white mantle. Above him was brilliant sunshine. But the cold was intense and everyone on board was half frozen. The voyage to Australia was to be accomplished under all conditions of weather, from blinding snowstorms to tropical heat, from glorious sunshine to tropical rain. The ninety mile an hour snowstorm which was raging was so bad that Ross Smith made a note in his diary at the end of his first stop, " I am a silly ass for ever having embarked on the flight." But once started there was nothing to do but to go on. Curiously enough, Ross Smith always looked upon that first day of his flight as the worst part of his journey. And there was little doubt that it was a terrible journey, for he had flown 510 miles, from Hounslow to Lyons, on a day which was officially stated to be " Unfit for flying." But it gave him and his brother a confidence in the machine, a confidence in their ability to steer a straight course by it, which nothing else would have given them.

The next stage was from Lyons to Rome, but owing to the late morning start from Lyons, the Vimy was forced to land at Pisa just as darkness set in. Then came the first delay for that night, and the following morning it rained in sheets and the Vimy, in trying to get off, got stuck in the mud. And when the following day the machine did get off, Sergeant Bennett had to make a flying jump to get on board just as the aeroplane was beginning to taxi across the ground preparatory to rising! The whole way to Rome was a fight against wind and rain, and the machine landed in Rome late in the afternoon, a whole day late on schedule.

The weather was very bad all over Europe at this time, and when the Vimy rose from Rome the following day it was so windy and bumpy that the great six and a half ton machine was tossed about like a leaf, often being bumped up and down as much as 500 feet. Ross Smith decided to land at Taranto and fly across the sea to Crete the following day.

It seemed as though the weather would never clear. From Taranto, the following day, the clouds and driving rain forced the pilot to fly only 800 feet above the sea. It was impossible to see far ahead. Once, coming through a bank of cloud, the aeroplane emerged close to a rocky island off the coast of Greece, and only by turning sharply at right angles was Ross Smith prevented from dashing his machine to pieces on the precipitous rocky cliffs. At Suda Bay the weather changed to sunshine, but the following morning on starting there was the usual driving rain. From Suda Bay to Cairo, 250 miles of sea had to be crossed, and the total flight was 650 miles. It was accomplished in seven and a half hours.

It was thought that once the airmen reached Cairo the weather conditions would improve, but the very first news received in the morning was from Palestine, saying, "Weather conditions unsuited for flying." Moreover, it was raining. Not a single day since it had left England had the Vimy failed to meet rain. It was enough to dishearten less courageous men than Ross Smith. But he knew that every hour might be of importance, and that if it were possible to fly, no matter how bad the conditions, then he must up and fly.

From Cairo the weather still remained bad, and over Ramleh the rain came down in torrents, cut the faces of all four on the machine and nearly blinded them.

It was not until the Vimy was over the Sea of Galilee that the weather began to improve, and shortly afterwards the machine landed at Damascus, one of the great ancient cities of the world welcoming the most modern invention of the world.

Though the weather was fine when Ross Smith and his companions went to bed, it was raining heavily as usual when they woke up. It would seem as though the storm had specially arrived at Damascus in time for the Vimy to take the air, for actually less than ten miles out of the city the weather was fine again. The next objective was Bagdad, but owing to darkness Ross Smith was compelled to land at Ramadie, about 40 miles away.

For the first time since they had left London Ross Smith and his companions found the promise of the following morning to be a fine one. They were now flying over the country of one of the most ancient civilizations in the world, over the great land of the Tigris and the Euphrates. For once the weather was all that it should have been, and at 100 miles an hour the great twin-engined aeroplane flew over Bagdad and on to the vast aerodrome at Basra.

Already the four on board were beginning to feel the strain of flying day after day. The end of the day's flying did not mean rest, for upon them depended the success of the whole undertaking, and petrol and oil tanks had to be refilled, controls overhauled and so on. At the end of every day's flying there was at least three to four hours' preparation required for the next. All four slept well at nights in consequence. Most nights Ross Smith and his companions only obtained four to five hours' sleep, for they were up by 4.30 every morning. It was a race against time every day.

The Vimy reached Basra on 22nd November, and the following day rose, with Bundar Abbas, 630 miles to the south-east, for their objective. The weather had at last turned fine, but the aviators were faced with another terror. The ground below them for hundreds of miles was almost impossible for landing, and if the engines had failed it would have meant either crashing or diving into the Persian Gulf. It was with great relief, therefore, to all that the long journey to Bundar Abbas was accomplished without any incident.

The next day's stage was even more unpleasant in prospect. For one thing it was another 100 miles, 730 in all, to Karachi, and over mountainous isolated country infested with tribesmen, who might not be too friendly in the event of a forced landing. That part of the journey took 8½ hours, and so monotonous was the country below him that Ross Smith had the greatest difficulty in keeping awake.

Karachi was the aerial gateway of India, and the next stop was at Delhi, 720 miles away. The weather for flying was now really perfect, though when nearing Delhi a violent wind tossed the machine from side to side, and it required all Ross Smith's flying skill to keep his aircraft on a level heel. Landing at Delhi meant that half the wonderful journey was over, that in thirteen days 5790 miles had been flown! Yet but fifteen years previously as many feet was considered a wonderful flight. Actually the last 2100 miles had been flown in 25 flying hours. All four men were so tired out that they were compelled to take a full day's rest in Delhi before proceeding on the next stage of their journey, to Allahabad, which was reached after four and a half hours flying the following day.

Allahabad to Calcutta, Calcutta to Akyab, Akyab

to Rangoon, were the next three stages. The four adventurers of the air were now entering on the worst and most hazardous part of their journey. Landing places were few and far between, and there was always the knowledge that if anything went wrong with the engines there would be the inevitable crash, and the attempt to fly to Australia would be over. No mother ever looked after her children so carefully and tenderly as did Sergeants Bennett and Shiers overhaul those engines every night after landing.

From Rangoon to Bangkok high mountain ranges and dense jungles of an unknown country lay below the machine. The very maps Keith Smith had of the country were so woefully lacking in detail that they were almost useless. The dreaded monsoons were due, to make matters worse, and heavy cloud banks and high mountain ranges forced Ross Smith to fly at 11,000 feet. Even then he was flying through a dense blanket of mist. This was a terribly anxious part of the journey. The ground could not be seen, while it was certain that only a few thousand feet below jagged mountain tops were rearing their crests into the sky. An engine failure at this juncture and the Vimy would have been smashed to pieces on the rocky mountain sides, for the clouds would have hidden the danger until the machine actually dashed into it.

Flying in cloud is one of the worst possible experiences. All sense of direction quickly becomes lost, and the pilot has to rely implicitly upon his instruments and often upon his own instinct. The machine is liable quickly to get out of all control. For an hour the Vimy literally felt its way across the great mountain range in Burma, an hour's nightmare for the

pilot. No man was more relieved than Ross Smith when he sighted Don Muang aerodrome, twelve miles from Bangkok. For hours he had been flying in cloud with the certain knowledge that even if there had been no cloud, there was no place to land in that vast stretch of impenetrable, unexplored forest and jungle.

Leaving Don Muang, the machine ran into the monsoons. It didn't rain, it just poured down a continuous sheet of water. The rain was so bad that both Ross Smith and his brother were compelled to take off their flying goggles, and peer ahead with the rain driving into their unprotected eyes at 90 miles an hour. Each man took in turn to peer ahead for a few minutes, while the other rested his eyes. For three hours the machine drove on with these few minutes change and change about. It was a test of human endurance which has seldom been equalled. If it had been possible to land anywhere the machine would have been brought down. But there was no sign of a possible landing-place anywhere. So bad was the visibility that once the machine missed crashing into a hill literally by feet only, and it was only saved by the quickness of the pilot in turning and climbing. He had arranged to land at Singora, half-way between Bangkok and Singapore, and about an hour's flight from there the Vimy out-raced the storm. Landing there, the first accident happened to the machine. The tail skid was torn off by a tree stump on the landing ground.

Ten inches of rain fell that night, and the four weary men, with eyes that ached after their fight through the wet the previous day, were only too glad to take an enforced rest while fresh petrol supplies were being brought from Penang. Another day had

been lost, and they were wondering if they would get to Australia within the time limit set.

From Singora to Singapore the weather improved, and the Vimy made the journey without incident, landing there on December 4th. Eight more days to go, 2500 more miles to fly, most of it over mountain, jungle or a swamp. It was as hot in Singapore as it had been cold flying over France. Ross Smith and his companions were now so physically tired that they decided, before facing the remaining part of their flight, to have a day's rest, or part of one rather, for part of their day's rest consisted in giving the aeroplane a thorough overhaul.

Leaving Singapore, the Vimy crossed the Equator, and the weather began to change definitely for the better. Some 10,000 miles had been flown, and the powerful engines were running as well as they had on the first day of the trip. It was a great tribute to the makers. From Singapore to Kalidjati, the next stop, was 650 miles. Between the two there was no possible landing-place, but the whole journey was made without any trouble. The weather was as favourable now as it had been unfavourable in the first part of the journey. The next stop after Kalidjati was Surabaya, a large part of the way being flown over rice fields. The aerodrome at Surabaya was so sodden that a bamboo matting track had to be laid down for the machine to get off, and the machine was delayed twenty-four hours while sufficient mats were collected.

Surabaya to Bima, the next stop, was a stretch of country where there was not a single square foot where the Vimy could land safely in an emergency. But the distance was safely negotiated, and there was now less than 1000 miles to go to Port Darwin, and only one

more stop, at Atamboea. Most of the last lap of the great flight was over the sea, and at half-past eight on the morning of 19th December the great machine rose for the last time in the air before landing in Australia. It was the worst lap of all in one way, as for five hours the airmen would be out of sight of land. The Australian Government had arranged for a warship to patrol that stretch of water in case of accidents. At two o'clock the Australian coast line was sighted, and at three o'clock the Vimy landed.

She had flown from London to Australia in 27 days 20 hours. There were only 52 hours to spare.

And so ended one of the greatest flights, if not the greatest flight, that has yet been made. The actual number of hours in the air was 135.

Remarkable as was the flight from England to Australia, another Australian flight, accomplished in 1924, was as remarkable in its way. On 19th May 1924, Wing Commander Goble and Flying Officer McIntyre reached Melbourne, and so accomplished a circuit of Australia which they had begun on 6th April. The machine used was a Fairey III seaplane. Part of the flight was carried out in blinding rain only a hundred feet above the sea. Unlike Sir Ross Smith, who had time to overhaul his machine and engines every day before the next day's flight, Goble and McIntyre had no opportunities to attend to their engine. Nor had they any prepared aerodromes, or bases with facilities for spares and repairs. Their machine was three years old, yet it accomplished the whole journey practically without a mishap, a wonderful testimonial in itself to the reliability of modern aeroplane construction and engines. The total distance of 8568 miles was flown in 90 hours of actual flying

time, a little under 90 miles an hour. The average distance flown each day was 200 miles.

The Fairey III D seaplane, which made the circuit of Australia, is a single engined biplane, fitted with a Napier Lion engine of 450 horse-power. It is the standard general service seaplane of the Royal Air Force.

In 1924 Major P. L. Martin and other United States airmen flew round the world in four Douglas "World Cruisers." Each machine carried two men, and was specially fitted with extra petrol and oil tanks to enable a distance of approximately 2200 miles to be flown at a stretch. They were single-engined biplanes, fitted with 420 horse-power Liberty engines. These engines weigh less than 2 lbs. per horse-power, and proved very reliable. The total distance covered was 27,534 miles in 351 hours flying time. The journey was not carried through without mishap, Major Martin crashing near Chignik and Lieutenant Wade landing in the sea between Kirkwall in the Orkneys and Thorshavn in the Farœ Islands, the machine becoming a total wreck.

Another round the world flight was attempted by Squadron Leader A. S. C. MacLaren on the Vickers Vulture amphibian, but after flying 13,000 miles, the machine crashed in a fog in the Komandorski Islands, in the North Pacific, and the flight was abandoned. A further attempt in the same year (1924) by Major Zanni of the Argentine army in a Fokker C. IV, fitted with a 450 horse-power Napier Lion engine, was also abandoned after 12,000 miles had been covered.

Early in November 1925 there ended at Rome a very amazing flight, that by an Italian airman, the Marquis de Pinedo. The flight was from Italy to

Japan, *via* Australia and back again, a total distance of 35,000 miles. The flight was amazing from the simplicity of the means by which it was accomplished. No elaborate preparations were made. The pilot set out alone, taking with him only the clothes in which he stood up, and buying stores and supplies as he went. The flight broke all records for distance flown, and all speed records over long distances, in the return journey from Tokio.

The machine used was a Savoia seaplane with a 450 horse-power Lorraine-Dietrich engine, and altogether the airman was six and a half months on his long flight, including a five weeks' halt at Melbourne and a three weeks' enforced stay at Tokio, where the engine was changed. This is the longest sustained flight which has yet been made. The conditions under which it was made, however, mark a milestone on that aerial pathway which leads to the time when round the world flights by the same machine will be regularly accomplished.

At 4.20 p.m. on Saturday, 13th March 1926, Mr Alan J. Cobham landed at Croydon Aerodrome, after a remarkable flight from London to Cape Town and back, a distance of 17,000 miles. The flight, which was *via* Cairo, Khartoum, Bulawayo and so to Cape Town, was undertaken with the object of finding out the possibilities of air routes between London and Cape Town and intermediate places. During the journey the machine, with an unchanged air-cooled engine, went through every kind of weather, including rain, gales, sandstorms and intense tropical heat, a fine tribute to the construction of the engine and the aeroplane itself. Once, for example, the pilot ran into a sandstorm which was so thick that it was im-

possible to say which was the desert, the air or the sky! And the storm, contrary to all local beliefs, was over 15,000 feet high. Mr Cobham was also responsible for the remarkable flight to India and back with Air Vice-Marshal Sir Sefton Brancker the previous year.

Many other amazing flights have been carried out, and are being arranged for, but space does not allow a detailed description to be given here. Those which have been described have been chosen as examples of the wonderful advance in flying which has been made since those days in 1903, when Wilbur and Orville Wright flew for a minute or so at a time, and considered a flight of ten miles something at which to marvel. Soon 10,000-mile flights will become so common as to excite no comment.

CHAPTER V

RACES AND RECORDS

THE early years of flying by means of heavier-than-air machines received much encouragement by the offer of prizes to be won for certain performances. It would be invidious to pick out one prize more than another, but their effect on progress can hardly be over-estimated. Some of these prizes are small, as the Schneider Cup for the winner of a seaplane race, but the honour of winning them is great. A brief account of some of the prizes offered, and the way they were won, is necessary to make a complete and proper record of the story of the aeroplane. There is not the slightest doubt that, apart from wars, nothing more conduces to technical and other advancement in anything as the offer of high rewards for the accomplishment of some feat, for the attainment of some object which is apparently impossible or extremely difficult at the time of offering. It gives incentive and stimulates keen competition, making progress so much more rapid and leaving behind records of successful attempts and glorious failures which inspire for the future.

It was the offer of a prize which made Louis Bleriot fly the English Channel; which caused Hawker and Grieve make their wonderful attempt to cross the Atlantic and caused Sir John Alcock and Sir Arthur Whitten-Brown to succeed; which made Sir Ross Smith fly half-way round the world from London to Adelaide; which has made flying what it is now.

Some of the attempts to win these prizes are described

in the previous chapter. Here a brief account only can be given of the more important of the remainder. One of the earliest and most important of the prizes offered was that of an annual prize for ten years, made by Messrs Michelin. This prize was offered for the flight of the longest duration with the added condition that each year the flight in question should last twice as long as that accomplished by the previous winner of the prize.

Appropriately enough, the prize was first won in 1908, on 18th December, by Wilbur Wright, the first man to fly on a power-driven aeroplane, with a flight lasting 1 hour 53 minutes 59 seconds. In the following year a special Michelin Cup was offered for the year for the longest flight made by British pilots on British built machines. This prize was first won by J. T. C. Moore-Brabazon, with a flight of 19 miles. In 1910 there was a most exciting contest for the British Cup, and this contest in itself shows what great advances had been made in an art which was almost non-existent at the beginning of 1908. T. O. M. Sopwith flew just over 100 miles competing for the cup. Four days before the competition for the year closed, Alec Ogilvie increased the distance to 142 miles, and was looked upon as the winner. But on the last day of the competition Sopwith made a fresh attempt, and flew 150 miles, only to be beaten the very same day by that remarkable and persevering pioneer, S. F. Cody, who flew 185 miles over Laffan's Plain on a machine of his own design. The French Michelin Cup was won by Tabuteau, with a wonderful flight of 365 miles in 7 hours 48 minutes.

The year 1911 was to prove the turning point in the history of aviation, for that year was to prove once

and for all that aeroplanes had come to stay. Despite the many flights which had been carried out since Wilbur Wright rose on his machine in France in August 1908, despite the crossing of the Channel by Bleriot, and other signs that flight was now an accomplished fact, the public were still suspicious that the new art was not going to lead very far. Strong winds still kept flyers on the ground, and accidents were frequently being reported in the newspapers.

But in that year five big races took place which focussed public attention more than anything else. These were the Paris-Madrid race won by Vedrines, the Paris-Rome race won by Lieutenant Conneau of the French Navy, the circuit of Europe race, the circuit of Britain race, and the race for the Gordon-Bennett cup. Perhaps the circuit of Britain race was the most important as far as Great Britain was concerned, for it roused an enthusiasm which was never to die out, and enabled many thousands of people to see an aeroplane who had never seen one before.

The rules for the race round Great Britain were more stringent than those for previous air contests, so that it was felt that this race would be a more severe test of the capabilities of aeroplanes. Previously if a machine broke down in a race from engine failure, for example, a new engine was hurriedly fixed in the aeroplane and the flight continued. But for this circular contest, essential parts of the aeroplane and engine were officially stamped, to make sure that no really vital changes were made during the race.

The route was divided into sections. A start was made from Brooklands, and competitors were compelled to descend at Hendon, Edinburgh, Bristol and Brighton, finally landing at Brooklands again. At all

these control points, the machines were examined. The race provided more spectacular thrills than any previous aerial race had done. Seventeen pilots started and all landed safely at Hendon. But after that, one by one, they began to drop out.

The second stage, *via* Harrogate and Newcastle for Edinburgh, had two competitors, Lieutenant Conneau and Vedrines, both Frenchmen, who soon outdistanced all others. From Edinburgh onwards the contest became a see-saw duel between these two. The 1010-mile race was eventually won by Conneau in 22 hours 28 minutes, his rival being beaten by one hour.

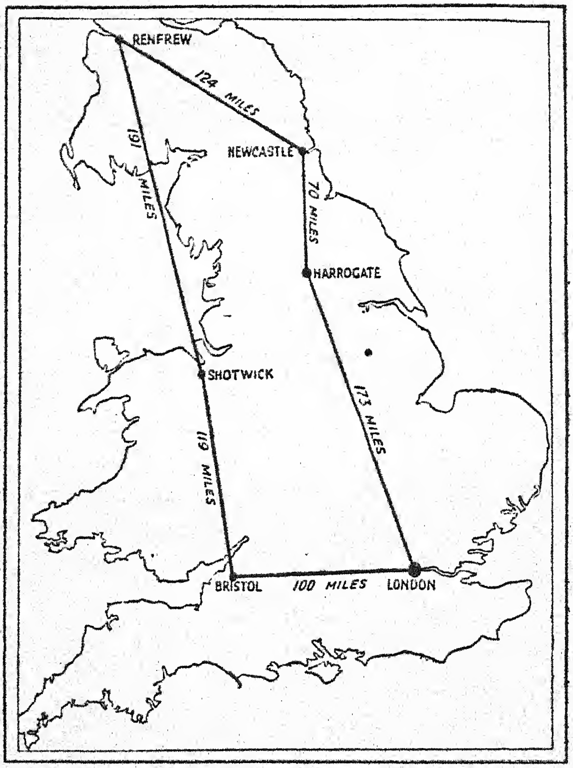
In Great Britain the chief aerial event of the year is undoubtedly the race for the King's Cup. This race was first started in 1922. Machines are entered by owners and flown by well-known pilots, much in the same way that horses are entered for the Derby.

The race is now for a double course of Great Britain, and the actual course is varied each year. The first race was won by Captain F. L. Barnard, flying a D.H. A machine. The following year the race was won by F. T. Courtney, famous for many long distance cross-country flights. The 1924 race was won by Mr Alan J. Cobham, who flew to India and back with General Sir Sefton Brancker, to survey the Cairo-Karachi air-mail route in 1925.

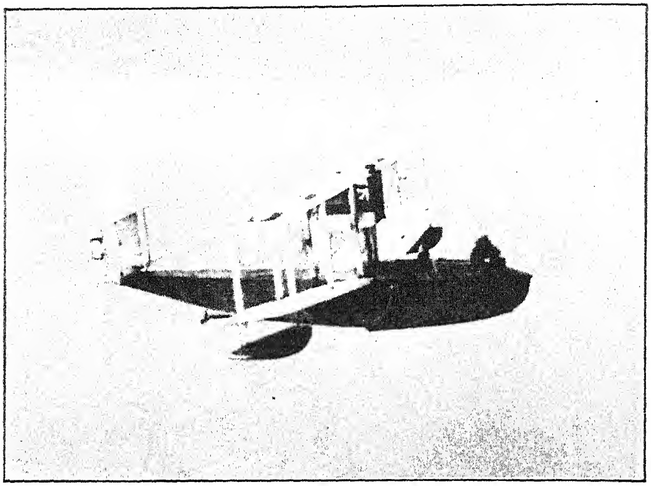
The 1925 race for the King's Cup occupied two days. The first day the course was London-Harrogate-Newcastle-Renfrew-Shotwick-Bristol-London. At each of the towns *en route*, the pilot had to descend for half an hour, and for an hour at Renfrew. The 1925 race was won by Captain F. L. Barnard, the winner of the first race, and the two circuits were covered at the

remarkable average speeds of 130 miles an hour and 151 miles an hour.

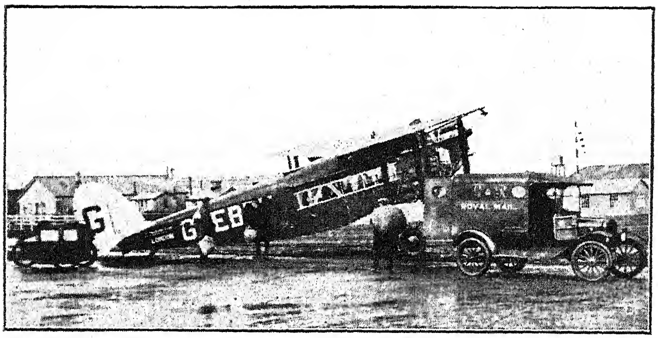
The cup is open for competition by any person who is a British subject. The pilot must also be a British



subject, and the machine must be entirely constructed in the British Empire. The race is a handicap, so that it is not necessarily the fastest machine which wins the race. Many other subsidiary prizes are



Vickers Viking Amphibion in flight.



The Christmas Mail for Paris.

PLATE IV.

offered in connection with the Blue Riband of the air, and the race has now become the most important aerial sporting event in Great Britain.

Another important race is that round London, the Aerial Derby. It is a handicap race, and was first flown in 1912 over a course of 81 miles. The circuit was round London, and was won by Gustave Hamel for the first time on a 70 horse-power Gnome Bleriot machine. The start and finish were at Hendon, and the turning points were Kempton, Sandown, Purley, Purfleet, Epping and High Barnet. Though not a score of years ago, comparatively few people had seen an aeroplane fly, and fewer still aeroplanes racing. The race seized the imagination of those living in and near London, and several million people watched the first aerial Derby from various vantage points on the route. Actually, T. O. M. Sopwith was first home in 1912, but he was disqualified through failing to turn round a mark properly.

The second race was over a course of 95 miles, and was also won by Hamel, at 76 miles an hour. The third race, in 1914, was won at a slightly less speed by W. L. Brock, and no further races took place until 1919, when, in June, was held the Victory Derby. During the Great War the design and construction of aeroplanes and aeroplane engines had improved by leaps and bounds, and the results of these improvements were seen by the speeds which were reached. Just before the war, 75 miles an hour was considered a very high speed, and the 80 horse-power engine was the one in greatest use. In 1919 Captain Gathergood won, with a speed of 129 miles an hour on an Airco 4R machine, fitted with a 450 horse-power engine. Such great speeds necessitated the circuit being covered

twice to make a good race. The winner's speed steadily increases each time the race is flown, a speed of 192 miles an hour being reached in 1923 by the Gloster machine fitted with a 450 horse-power Napier Lion engine and flown by Laurence Carter.

The Schneider Cup is an international trophy founded in 1912 for the best seaplane of the year. In that year M. Jacques Schneider presented a trophy to the Aero Club of France for competition open to any country for sea-going aircraft, over a distance of about 200 miles. To eliminate freak craft specially built for the race, part of the conditions of entry are that each entrant must undergo certain very severe tests of sea-worthiness, as riding at anchor for so many hours, taxying on the water, taking off and landing.

The entry for the cup from any particular nation is limited to three machines, and the Aero Club of the country winning the race any one year holds the trophy for that year, and is responsible for the organisation of the race, in its own waters, the following year. Any country winning the cup for three years out of five retains the cup for good.

The first race was won in 1913 by France, and was won by Provost, flying a Duperdussin seaplane at 45·4 miles an hour. The following year the trophy was won by England with a Sopwith seaplane at a speed of 86·4 miles an hour. From 1915–1918 no races were held for the cup on account of the Great War, and the 1919 race was held at Bournemouth. All the competitors met with accidents, except the Italian, who completed the course, but was disqualified through failing to fly round one of the turning points. The cup, however, was sent to Italy and raced for there, though Italy was not declared an official winner

for 1919. The cup was retained by that country in both 1920 and 1921, there being no foreign competition.

In 1922 a flying boat built by the Supermarine Aviation Company, and driven by a 450 horse-power Napier Lion engine, won the race. The pilot was Captain H. C. Biard, who won with a speed of 146·1 miles an hour, beating all three Italian entries.

The 1923 race was flown in British waters, under the conditions of the competition, at Cowes. The course was from Cowes to Selsey Bill and back, and it had to be traversed five times. There were three entries from America and three from France, and two British entries, one of which was the same flying boat which won the cup from Italy in the previous year. In the trial flight two of the French entries dropped out and one of the Americans. The race was won by an American Curtiss machine at a speed of 177·38 miles an hour. The Curtiss was fitted with a 465 horse-power D-12 engine.

In 1924 there was no race, and the 1925 race was held at Baltimore. There were three entries from America, two from Italy and two from Great Britain. The course was in Chesapeake Bay, over 189 nautical miles, in seven laps over a triangle of 27 miles.

The British machines were the Supermarine Napier S4, flown by Captain Biard, and the Gloster Napier 3, flown by Captain Hubert Broad. The former had, before the race, set up a speed record for seaplanes of 226¾ miles an hour. The machines were fitted with Napier engines, developing 700 horse-power. The American entry consisted of three R3C1 biplanes, fitted with floats. The Italian machines, both Macchi flying boats, were both monoplanes. The race was

attended with a series of unfortunate mishaps to both the British machines, both crashing on the preliminary flight tests, and it was eventually won by Lieutenant Doolittle for America at the extraordinary speed of 234 miles an hour. There has been no contest in 1926.

So high is the speed of modern aircraft that in such a course as that at Chesapeake Bay, where the longest leg of the triangular course is 11 miles, it is impossible for the machines to get up to their top speeds. There are nineteen sharp turns in such a course, with a consequent slowing up at each turn, so that the average speed of a winning machine is considerably below its speed over a straight course.

There is probably a definite limit of speed over a triangular course of such a description, a limit set by the strain which the pilots can stand more than that set by the machines. It is not difficult to fly a straight course at 250 miles an hour, but it is a very difficult thing turning a corner at that speed. Very high stresses indeed are put upon the machine at such tremendous speeds, but machines can be specially strengthened up to withstand them. But it is a different thing in the case of the pilot. Too sharp a turn at speeds of 200 miles an hour and over may easily render a pilot unconscious, and, in fact, some pilots have momentarily lost consciousness while turning. Such machines, too, accelerate at such a rate that this alone makes the pilot feel dizzy, and they have to be specially trained to withstand the ordeal.

The races for the Schneider Cup are to aviation what international motor car races are to motoring. They not only teach extremely valuable lessons, bring out new points in the design of both the aeroplane and the engines, but they bring a prestige to the winning

country which is worth having. What speeds it will be possible to reach cannot be said with certainty, but speeds of 300 miles an hour are easily within the range of practical construction, and if the Cup were flown for over a straight course, such speeds would undoubtedly be reached in the course of the next contest or so. But as long as the race is held over a triangular course, with comparatively short legs, it is doubtful if such an average speed will be reached, the strain being one which it is beyond the human body to bear.

It is instructive to consider the conquest of the air from the point of view of some records which have been made. Wilbur Wright, on 21st September 1908, at Auvours in France, created a sensation by flying at 27 miles an hour. Now, very few aeroplanes, indeed, land at that speed. It was not until four years later that Jules Vedrines flew at over a hundred miles an hour. At the outbreak of the Great War the official fastest speed at which an aeroplane had ever flown was 124 miles an hour, and it was thought then that the limit of aeroplane speeds was being reached. During the war, however, this speed was regularly exceeded by many machines. Now speeds of 160 miles an hour are called for as a matter of course in certain types of war machines, while speeds of over 260 miles an hour have been exceeded on a number of occasions. On 11th December 1924 a speed of nearly 278 miles an hour was officially reached by a Frenchman on a Bernard monoplane. And there is no reason to believe that this speed will remain unbeaten for long.

There is a human limit to speed, and this will ultimately limit the speed of an aeroplane. Aeroplanes built for very high speeds have exceedingly powerful engines, and they accelerate so fast that there is a

danger to the pilot of blood vessels bursting, or that he will lose consciousness temporarily. This danger is increased when the aeroplane tries to turn at these high speeds, and it seems fairly certain that unless men are specially trained for racing that the limit of the speed an aeroplane can reach will depend upon the strain the pilot can stand.

On 18th December 1908 Wilbur Wright astonished the world by rising to an officially recorded height of 360 feet in an aeroplane. A year later Hubert Latham, who made such a gallant attempt to fly the Channel in the early days of flying, had increased this record to over 1000 feet. In another year, 9th December 1910 to be exact, the altitude record had been raised to 10,000 feet, and on 28th December 1913 to 20,000 feet. On 10th October 1924, a height of over 40,000 feet was reached by M. Callizo on a Goudron-Lesseure monoplane, over seven and a half miles above the surface of the earth, two miles above the top of Mount Everest.

Height records require a considerable amount of preparation to carry out. In the extremely rarefied atmosphere which is met with at 30,000 feet and more the pilot not only has the greatest difficulty in breathing, but he is faced with a temperature many degrees below zero. A pilot making an attack on a height record takes up with him oxygen cylinders, so that he can breathe without difficulty, and is provided with electrically-heated clothing to keep him warm. Even with these precautions pilots have been known to lose consciousness at these great heights, and not to have recovered until their machine has dropped many thousands of feet. The pilot is faced with the very low pressure of the atmosphere when he is some miles above

the earth, and this may make him sick and giddy. And it is not only the pilot who suffers. An engine which works well on the ground will refuse to work at all at 30,000 feet. The reason for this is that the air is too rarefied to provide a proper explosive mixture. Special engines have to be provided for aeroplanes flying at great heights, supercharged engines. In these engines air is forced into the engine to provide the necessary explosive mixture.

When Wilbur Wright flew for a little over an hour in 1908 the fact was chronicled throughout the world, and many thousands of articles were written on the coming of the air age. In less than a year this record had been multiplied by three, and on 10th July 1914 Boehm managed to remain in the air for over twenty-four hours continuously. In July 1924 MM. Coupet and Drouhin, taking turn and turn about, remained in the air on a Farman biplane for 37 hours 59 minutes.

CHAPTER VI

The Great Airways of the World

It was only natural, as soon as flights of 100 miles and more were being regularly made, that many people prophesied that in a few years everything which had to be carried any distance would be carried by aeroplane. In fact, many went on to predict that the day of the railway and the steamship was over, and that by 1950 the airship would be as dead as the dodo.

Though the prophesies of enthusiasts have not been fulfilled, and as far as regards the extinction of the steamship and other forms of transport, probably will never be fulfilled, much progress has been made in the organising of great air routes, over which passengers, mails and goods will be carried as regularly and more swiftly than they are now by railway and steamship. There will always be room for the latter two types of transport, for high speed of transport always means a higher cost than slow speed, and for that reason alone many things will be sent by land and sea when time is not an important consideration.

But mails and passengers, perishable goods and valuable goods will more often be sent by aeroplane. The time will undoubtedly come when much of the food supplies of the world will be carried by great air cargo steamers, so that they can be sold as fresh as possible.

Few people nowadays quite realize how many air routes there are in existence and how many are being

planned. It is now possible to fly any day, just as it is possible to travel by train or steamship any day, from London to Paris, Brussels, Cologne, Amsterdam, Bremin, Hamburg, Berlin, Copenhagen, Stockholm, Leipzig, Stuttgart, Basle, Zurich, Geneva and Lyons, to mention only a few European towns. Flying services run between most of the big towns and capitals of Europe, not casually as required, but day in and day out in every kind of weather except the densest fog, carrying passengers, goods and mail. Yet until the Great War was over there were no regular flying services of this nature in any part of the world.

It was on 25th August 1919 that the first daily aeroplane was started between London and Paris. Even then the Great War had not taught people what new wonder had flown into their midst. The very people who had, night after night, looked up into the skies from 1914–1918 wondering if German bombers were going to rain a pitiless hail of death on their towns, were slow to realize that these very machines which could carry huge weights of bombs for many miles could just as easily carry people and luggage.

One, two, three passengers a day flew to Paris in the first few weeks the great air expresses began. To and from Paris the enterprising, energetic and far-seeing men who ran that air service, who blazed the first great international air route, counted themselves lucky if they had as many as thirty passengers in a week. In those days London's aerial port was Hounslow. Now it is Croydon, and a thousand people a week leave from and arrive at the finest air station in the world during the summer months.

The aeroplanes which carried passengers in those

days were hastily converted war planes, in which the passengers sat huddled, cramped, often miserable. Most flew because they wanted to boast that they had flown, and few wanted to fly again. Now great air liners fly along a dozen international air routes. Passengers have comfortable cabins in which to sit, easy arm chairs, and all the amenities which travellers have a right to expect in any other form of travel.

Since that day in August 1919, when the first daily air service began, regular services have sprung up, not only in Europe, but in America and other countries. Here is an extract from the Imperial Airways Bulletin No. 4, which gives some idea of the way the habit of flying is growing.

Cross-Channel Traffic from 1st April 1924 to 26th September 1925—

Flights made - - -	7198
Mileage flown - - -	1,420,274
Passengers carried - -	20,140
Freight carried - - -	1170 tons.

Well over 5,000,000 miles were flown in the first six years between London and the Continent on British commercial machines, and over 60,000 passengers were carried. In August 1919 only 225 air-route miles were being operated between London and the Continent, but by August 1925 this distance, for British machines alone, had increased to over 1400 miles, flown day in and day out.

The same bulletin adds that an Imperial Airways aeroplane, carrying six passengers, flew from Amsterdam to Croydon, a distance of 265 miles, in 110 minutes, at an approximate speed of 150 miles per hour. Another Imperial Airways aeroplane flew from

Croydon to Zurich, 545 miles, carrying £130,000 of bullion, in 4 hours 52 minutes.

By the end of 1925 commercial aviation in Europe was practically in the hands of two powerful groups of aviation companies, the International Air Traffic Association, consisting chiefly of companies formed in ex-allied countries and the German company, Deutscher Aero Lloyd; and the Europe-Union, a combine of various companies using the famous Junker machines. But a strong movement is on foot to combine all these companies into one, so that there shall be a truly international air service all over Europe, an international League of Nations in the air. And such a league will go far towards promoting international goodwill which must, ultimately, be the only sure foundation of an everlasting peace.

Just as the great sea routes are made safe for shipping by the warning lighthouses, so the great air routes of the world are steadily being made safer by aerial lighthouses, lighthouses which throw powerful beams upwards. On the London-Paris route, for example, there is first of all the great red beacon at Croydon, then the Tatsfield Lighthouse, followed by two powerful aerial lighthouses at Penshurst aerodrome. From there to the coast the night flyer sees the lighthouses at Cranbrooke, Lympne and Littlestone. As soon as the Channel is crossed, the Inglevert lighthouse comes in sight and thence the welcome lighthouse of the great Paris air port, Le Bourget. These lights and others are more than necessary now that the night service for goods between London and Paris is being established.

In Australia aerodromes and emergency landing grounds have been prepared on all the principal

routes between capital cities of each state, as well as in other parts of Australia. On the Perth-Derby mail route in Western Australia, for example, there are 9 regular aerodromes and 16 emergency landing grounds in the 1440 miles covered by the service, which has now been running some years. On the Charleville-Camooweal service in Queensland, a route of 823 miles, there are 10 aerodromes and 13 emergency landing grounds, while on the Adelaide-Sydney service, a route of 790 miles, there are 6 aerodromes and 24 emergency landing grounds.

A brief description is given here of the London-Amsterdam air route as seen from the air. The air passenger leaves Croydon, or Wallington, as it may in future be named, and flies over Lympne, where the pilot reports by wireless before crossing the Channel from Folkestone. From Folkestone to the French coast is about 15 minutes' flight, during which the air passenger can see tiny specks on the sea, cross-Channel steamers and ships ploughing their comparatively slow and laborious way through the waves. Over Sangatte the pilot wirelesses his safe crossing to the French air station at St Inglevert, and, turning, follows the French coast north, past Dunkirk with its two jetties and maze of shipping.

From Dunkirk the aeroplane is soon over Belgium, and past Ostende and Zeebrugge, whose historic Mole juts far out to sea. Then follow the Dutch islands and the characteristic chessboard dyke country of the mainland. When over Rotterdam, long rows of shipping can be seen lying at anchor. Windmills, canals and chessboard fields follow with monotonous regularity as the great Dutch seaport is left behind, and shortly Amsterdam comes into sight, and the great

machine glides majestically down to Waalhaven, once marshland, but now a great air station. The whole journey has taken less than three hours!

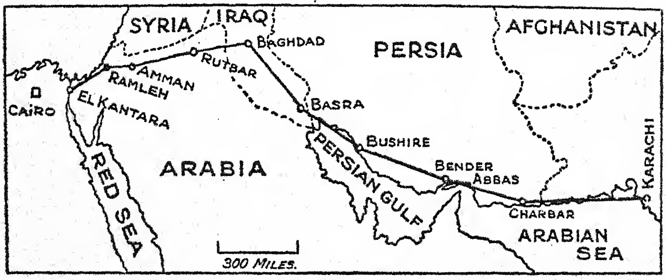
The following table gives an idea of the relative times taken to go from London to the towns mentioned by air and by boat and train. It will be seen that the flying time makes a very considerable saving.

London to	Time of Departure. A.M.	Noon.	P.M.	Flying Time.	Time by Boat and Train.
Paris	8.45	12.00	5.00	2½ hours	7¼ hours
Basle	8.45	..	..	7 "	15½ "
Zurich	8.45	..	..	8 "	19 "
Ostend	8.30	..	..	1¾ "	5¼ "
Brussels	9.00	..	..	2½ "	8 "
Cologne	9.00	..	4.15	3½ "	20 "
Amsterdam	8.00	..	..	2¾ "	11 "
Hanover	8.00	..	..	6 "	..
Leipzig	8.00	..	..	7¾ "	..
Berlin	8.00	..	..	8 "	25 "
Hamburg	8.00	..	..	6 "	18 "
Malmo	8.00	..	..	8½ "	35 "
Copenhagen	8.00	..	..	7½ "	34 "

A thousand-mile air route, the longest in the Old World, has been planned to start in 1926. Organised by the government of Soviet Russia, it will link up Southern Siberia with China, the route being from Udinsk to Pekin by way of Urga, the capital of Mongolia. At present, the only means of transport between Udinsk and Urga is by motor car, the journey occupying from 70 to 75 hours. By air, the distance will be covered in less than 4 hours. The more

difficult stage, from Urga across the Gobi Desert and on to Pekin, now takes 168 hours by car, but by air it will be accomplished in about 11 hours, thus making a total of 15 hours for the 1000-mile journey.

One of the great air routes of the world which will soon be in operation is that between Cairo in Egypt to Karachi in India. In 1925 Major-General Sir Sefton Brancker, the Director of Civil Aviation, piloted by Mr Alan Cobham, surveyed the whole area over which the new service will operate.



AIR ROUTE DIAGRAM.

This great new air route, the pioneer of the long distance airways of the world, has been instituted with the main object of saving time in the delivery of mails, though passengers will be carried as well. A letter to India at present takes 15 days, but when the new mail service is in full operation it will only take 6 days, considerably less than half the time. Mails will be delivered in the usual way by train and steamer to Cairo, and taken thence by the mail planes. Royal Air Force aeroplanes have actually been flying a fortnightly air mail service from Cairo to Bagdad since 1921. The map on this page shows the great

airway across the Arabian desert, along the Persian Gulf and Arabian Sea to Karachi.

An immense amount of preliminary work is necessary before such a long distance air route can be regularly flown. For the carrying of mails it is absolutely necessary that the aeroplanes not only fly regularly, but fly strictly to time. The service must be as reliable indeed as the train and steamship services are, and to make it as reliable just as much preparation is necessary in a way as is necessary when laying down a new railway track.

Every so many hundred miles proper aerodromes have to be laid out for the machines to alight and fly from day and night if necessary. Aerial lighthouses have to be built, huge petrol storage tanks have to be prepared, hangars built, day and night landing lights and signs to be erected, and so on. Intermediate between these big aerodromes landing places have to be prepared, so that an aeroplane can land in an emergency. Often, too, parts of the route have to be marked out in some definite way, so that the pilot is able to find his way. For instance, on the Cairo to Karachi route the whole distance from Ammam to Ramadi, across the desert, a distance of 450 miles, has had a guide line ploughed, and this line is visible from a considerable height. At intervals of 200 miles suitable landing grounds have been prepared where petrol is stored. The advantage of the air route to India is that the weather for the greater part of the year is much more favourable for flying than it is in the European air routes.

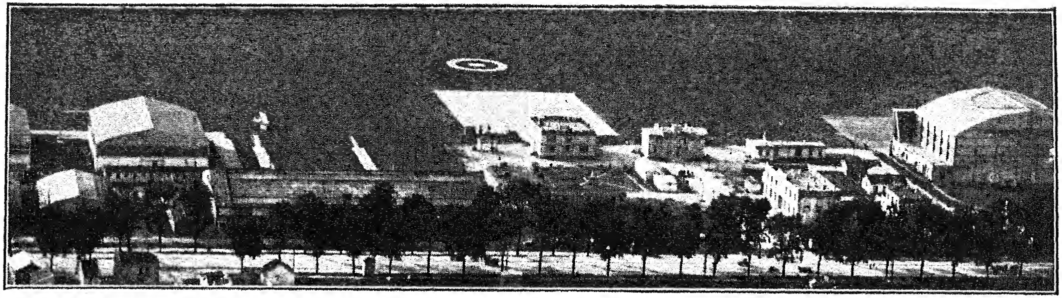
The air service from Egypt to India, *via* Bagdad and Basra, will begin by being a fortnightly one, and afterwards a weekly one. At the end of 1925 it was

announced that a contract had been signed between the Air Ministry and Imperial Airways to provide the carrying of mails for five years. Powerful three-engined machines are being used on this route, reducing the possibility of a breakdown to a minimum.

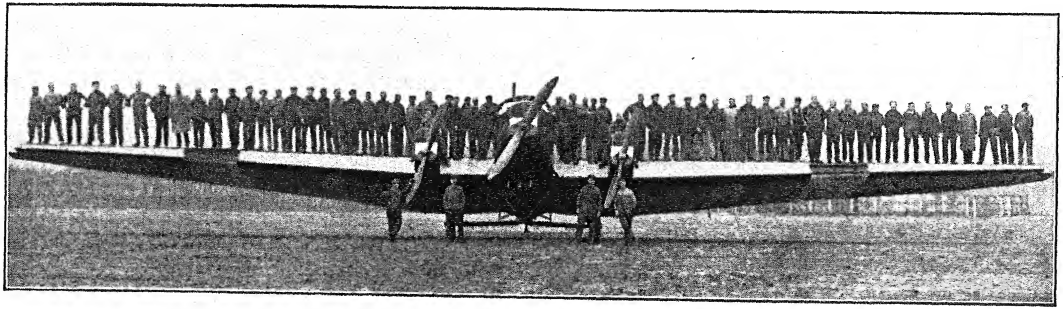
Air routes are being steadily opened in India, and many landing grounds have been prepared throughout the North-West Frontier Province, and Punjab and Baluchistan, and on the air routes from Bombay and Poona to Calcutta, and so on. The possibilities of aerial transport in such a vast and well-populated country as India have turned the attention of many firms towards the development of flying there, and in a few years the country will have aerodromes near all the big towns, and have a network of air routes along which mails, passengers and goods will be carried. The opening of the new air route from Egypt to India will give a considerable impetus to the projects now in hand.

In 1921 there began what is at present one of the longest regular air routes in the world, that from Perth to Wyndham in Western Australia. The aeroplanes over this route cover 2000 miles, and the run is made weekly, nine towns being passed over in the course of the run, seven being coast towns. Some idea of the length of this regular weekly passenger and mail service may be gathered from the fact that the distance covered is three times the distance between John o' Groats and Land's End. The actual time taken is 2 days 6 hours, as against the seven days minimum taken by steamships, which often only run once a fortnight.

The service has grown rapidly, a quarter of a million letters a year now being carried and many tons of



General View of Le Bourget Aerodrome, Paris.



The Junkers all-metal Monoplane supporting 63 men.

PLATE V.

goods. One of the towns over which the Western Australian Airways operate is Broome, noted for its valuable pearl fisheries and for the fact that the greater part of the population is black.

The flying mail is now in regular operation all over Europe, London, Paris, Amsterdam, Berlin, Basle, Copenhagen, Constantinople, and many other important towns, having a regular interconnecting service. Most of the mail services are also passenger and goods services. In Africa there are regular mail services between various important points, some experimental. These services will be largely increased in the near future. In America a regular mail service is flown between New York and San Francisco daily. The section from Chicago to Cheyenne is flown by night. In South America a number of mail services are running, and in Australia the Perth-Derby service in Western Australia is well known. This service, over a route of 1442 miles, is now in its fifth year. The machines used are D.H. 50A's and Bristol Tourers, both fitted with Puma engines.

The United States Air Mail Service is a division of the Post Office Department. Nearly 100 aeroplanes with 400 horse-power Liberty engines are used between New York and San Francisco. The time for the journey of 2640 miles is 32–34 hours, including stops on the way. The whole air route is being prepared so that it can be flown at night as well as by day. Air mail routes are under consideration from New York to Boston, Salt Lake City to Los Angeles, and between other important centres.

One of the most regular and interesting of the air mail routes is that which has been carried out for the last three years in Columbia, South America. There are,

in fact, a number of these routes, the longest being that between Barranquilla and Girardot, a distance of 625 miles. The air mail leaves Barranquilla twice a week at six a.m. and reaches Girardot at three o'clock in the afternoon, after calling for and picking up mails at four intermediate towns. From Girardot a mail service is maintained to Neiva, 125 miles away, and from Barranquilla another is maintained to Santa-marta. The machines used are all-metal Junker sea-planes, and each machine carries four passengers as well as the mails, and the service has been as regular as the train and steamboat service, a convincing testimony in itself to the statement that the aerial age has arrived.

Let us try to visualize some of the great air routes of the world. Some of these are already projected by those enthusiastic pioneers who foresee the near future. Many are yet to be planned. But this is certain, that most of the present generation will live to see the day when great aerial liners are flying to busy air ports all over the world, when air stations will have sprung up where now there are but deserted stretches of waste land, when busy towns will have sprung into existence where there are now but arid wastes.

Those air routes now in existence have already drawn significant lines across the maps of Europe and America. Every month sees a new route projected, a new one opened, a new line drawn on the air map. Already some 20,000 miles of airways have been opened in Europe alone.

Air travel is international, and international airway companies will in future control all the great air routes. From London there will be regular flying services to India and Australia, regular seaplane services to New

York and Canada. From Pekin to San Francisco flying boats will convey passengers and mails and goods. From San Francisco to New York, from New York to London, at 100 miles an hour these same passengers will fly if they so wish. London-Madrid-Dakar-Pernambuco-Buenos Ayres will be another of the great airways. Across Africa from Cairo to Cape Town the traveller in a hurry will be able to fly himself or send his goods in giant multi-engined machines, the tramp steamers of the aerial age.

At the time of writing this book, indeed, one of the preliminary African routes is under discussion, that between Khartum and Kisumu in East Africa. The saving in time on the total trip between London and East Africa will be eight days. Eventually the service will be extended to Cairo, joining up with the Imperial Airways service from Cairo to India.

CHAPTER VII

THE AEROPLANE ON THE GROUND

FEW people, seeing an aeroplane flying overhead, know how great must be the organisation necessary to enable it to fly regularly backwards and forwards between the great aerodromes. All these aerodromes have to be arranged on certain general lines, no matter in what part of the world they be, so that pilots have some general idea of the ground on which they want to land, and on that part of the aerodrome they should land. If all aerodromes were arranged in different ways, had different signalling arrangements, and different rules in other ways, a pilot would have to learn so much that he would get confused, unless he were regularly flying between the same two aerodromes.

For that reason the rules of flying and signalling and so on are international, and most nations have agreed to the same set of international air laws. So all pilots know when they approach a strange aerodrome exactly what they can do, what signals to give, and the meaning of the signals they have in reply. They will know what papers they will have to produce on landing, what papers they will have to sign before being allowed to rise again. The international air laws are based largely on the international laws of the sea, which have worked so well in the past.

The ground organisation necessary for safe flying, and, above all, regular flying, is very extensive. At every big aerodrome where passenger, goods and mail planes arrive and leave are ground engineers, who are responsible for inspecting and overhauling each aero-

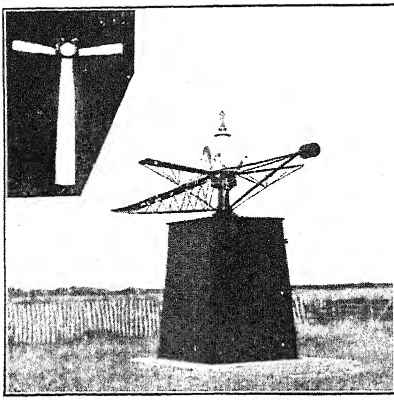
plane, and certifying that it has been properly examined and that it carries its correct papers. The pilot on landing, for example, may report that one of his engines is not exerting its proper power, or is misfiring occasionally. It is then the duty of the ground engineers to make a thorough examination of the engine, to find out what is wrong and put it right. If they cannot find the cause of the trouble and feel that something is radically wrong, it is their duty to report that the engine is not running properly, and that the particular aeroplane should not be allowed to fly until things are put right. It may be necessary to dismantle the engine completely or replace it with another engine. But so long as there is anything wrong which has not been diagnosed and put right, so long will that particular machine not be allowed to fly.

In the same way, all parts of an aeroplane have to be inspected, from the instruments to the controls, wires, and so on. An instrument may not be registering accurately, or the pilot may feel that it isn't, which amounts to the same thing; a wire may have become slack, or the fabric of the wings may be torn. The ground engineer must be on the look-out for all these things, keep an eye on the petrol and oil leads, and so on, so that every precaution is taken that there shall be no disaster in the air.

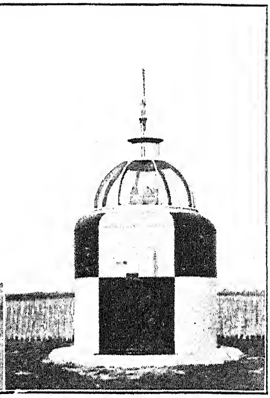
An important thing which the ground engineer and others have to make a note of before an aeroplane is allowed to fly is that she is properly loaded. It does not do to throw mail bags or goods and parcels anyhow into the aeroplane as they are thrown into the guard's vans of a railway train. And, moreover, aeroplanes cannot be overloaded in the case of a rush the same way that a railway train can. There is a definite limit

laid down for any particular aeroplane as to the weight she is allowed to carry, and this weight must not be exceeded under any circumstances. For example, it may be laid down that a certain aeroplane shall carry one ton of passengers and goods, and it is the duty of the officials on the aerodrome to see that this load is not exceeded. When the strength of an aeroplane is calculated, it is done so for a certain total weight known as the full flying load. This weight includes that of the aeroplane itself, the weights of pilot and passengers, and the weight of oil and petrol and other things necessary for a certain number of hours flying, usually six. If this weight is exceeded, then the aeroplane may not be able to stand the strain, in the same way that a bridge may be built for a certain kind of traffic and is unsafe for a heavier form of traffic. On many bridges appears a notice that no vehicle exceeding, say, six tons in weight is allowed to cross it, for the bridge is only built to a certain strength, and vehicles weighing more than six tons regularly crossing it would eventually break it. So if the weight carried by an aeroplane exceeded that laid down for it there is always the danger that it might break.

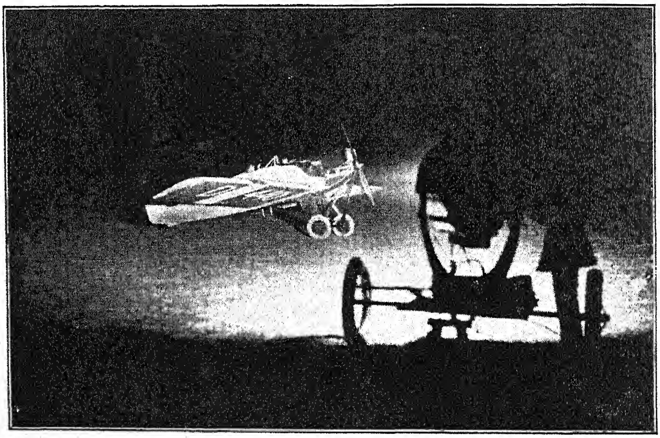
This danger is really twofold. An aeroplane which is overloaded rises sluggishly from the ground, struggling to get off, as it were, like an over-fat pigeon, and so is more difficult to control. She cannot climb so fast or fly so fast as she should do normally. A pilot accustomed to fly an aeroplane at a certain weight finds his machine is slow in answering to its controls if it is overloaded. It is almost like driving a strange motor car that is heavily loaded. It takes a certain amount of time to get accustomed to the behaviour of the overloaded machine, and there is



Night wind indicator at Croydon.



Aerial beacon at Croydon.



Night air mail leaving Berlin for Stockholm.

PLATE VI.

always a certain amount of danger with a machine which is slow in answering its controls. It is to eliminate all such sources of danger that the machine is not allowed to be overloaded.

Goods or mails cannot be packed haphazard in an aeroplane. If all the heavy goods were packed towards the tail end of the fuselage then the aeroplane would always want to fly with its tail down, and the pilot would have continually to make use of his controls to keep the machine flying on a level keel. This is an unnecessary exertion and strain on him. The technical staff on an aerodrome see that goods and mails are packed in such a way that the machine will fly without undue exertion on the part of the pilot. All the technical staff on an aerodrome, the ground engineers and so on, have to be properly qualified men, who must hold Government certificates as to their proficiency before they can inspect and pass machines as being fit to fly.

At all big aerodromes are repair shops where most repairs, adjustments and replacements can be carried out by skilled mechanics, and hangars where aircraft can be housed. Most of these hangars are owned or rented by the aeroplane companies which use the air port regularly. Large petrol and oil supplies have to be kept at all the air ports, and all this means a large ground staff. At aerodromes like Croydon and Le Bourget there are Customs sheds, just as there are at Dover, Ostend and other ports, with the usual Customs officials to examine luggage and passports. At every big aerodrome one of the most important officials is the Traffic Officer.

At all aerodromes, both in Great Britain and abroad, certain signals must be shown during the day and

certain lights at night. These signals or lights tell the pilot of an aerodrome as he approaches it, the direction of the wind, the name of the aerodrome, and so on. The name of the aerodrome is usually picked out in huge white letters on the ground or the buildings. Under the International Convention dealing with flying in 1919, it was agreed that aerodromes should be divided into three sections, one for landing on, one for rising from, and a neutral zone in between. Many other similar rules have been adopted, and are being modified in the light of experience, so that in a very short time all nations will have agreed upon a standard set of rules for the general ground arrangements of the big air ports.

In the Control Tower at Croydon sits the Civil Aviation Traffic Officer. On the desk in front of him is a large map marked with the air routes from London to the Continent. The Traffic Officer is one of the most important personages in any air port, and particularly so at Croydon. Without his permission no aeroplane may leave Croydon, and, what is just as important, no aeroplane is allowed to land. It must just fly and fly around till it is told it can land, if the Traffic Officer so decides.

The map in front of the Traffic Officer has on it a number of small differently coloured flags. Each of these flags represents one of the air liners *en route*, and each bears the colours of the company owning the air liner. At intervals the Traffic Officer moves the flags along the air route shown on the map, usually every ten minutes. He knows the speed of the machine the flag represents and the general direction and strength of the wind, so he is able to say approximately where the aeroplane should be. To make sure

that the positions of his flags are all right he is in constant communication by wireless telephone with the pilots.

The positions of aeroplanes may become very important. If a big machine is just ready to rise in the air, and another is signalled as being about to land, then it is quite clear that there is a chance of a collision, and it is the duty of the Traffic Officer to see that there is no risk at all. Upon him, indeed, depends much of the wonderful safety of the air, a safety which is higher than that of most forms of transport. The Traffic Officer warns the approaching aeroplane that another machine is about to rise, and gives him instructions to circle round till the ground is clear for him to land.

It is the Traffic Officer, too, who controls all the lighting arrangements for landing at night.

At Croydon small lighthouses are placed at each corner of the landing ground, while red lights are fixed on the tops of all objects which may prove obstructions, as aerial masts, towers, etc. A powerful flood light lights up the landing ground at night, while laid out on the ground is a series of electric lights in the form of two huge capital L's. A pilot guides his machine down one of the longer arms of the L and pulls up before reaching the shorter arm.

On the south-west side of the aerodrome is the great aerial lighthouse which throws a fan-shaped beacon extending from the horizontal to the vertical. The red aerial beam makes one complete revolution every three seconds.

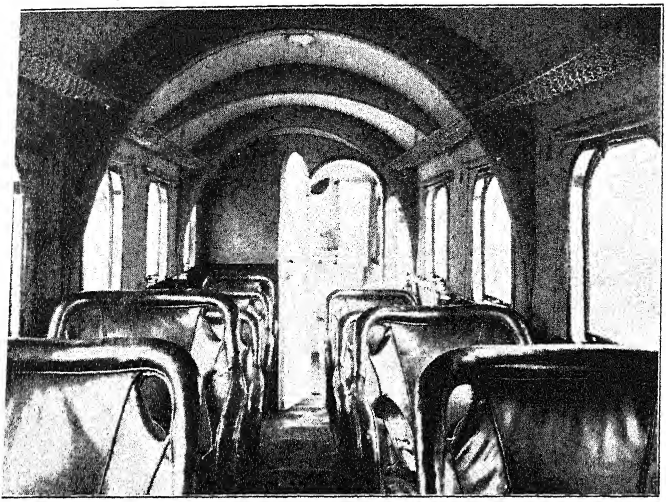
In 1925 the new system of Neon Lights were installed at the Croydon aerodrome. Two long parallel lines of these brilliant lights are sunk below thick plate-glass

covers across the landing ground. The Neon Lights are those familiar long thin tubes of reddish light now so commonly used for advertising purposes. At night aeroplanes land between these rows of guiding lights, looking like some great avenue of fire as they throw their reddish beams upwards. The length of the lights is about three hundred feet, and they have a remarkable power of penetrating mist and fog as no other lights have. Even under very bad conditions they can be seen for a considerable height above the ground.

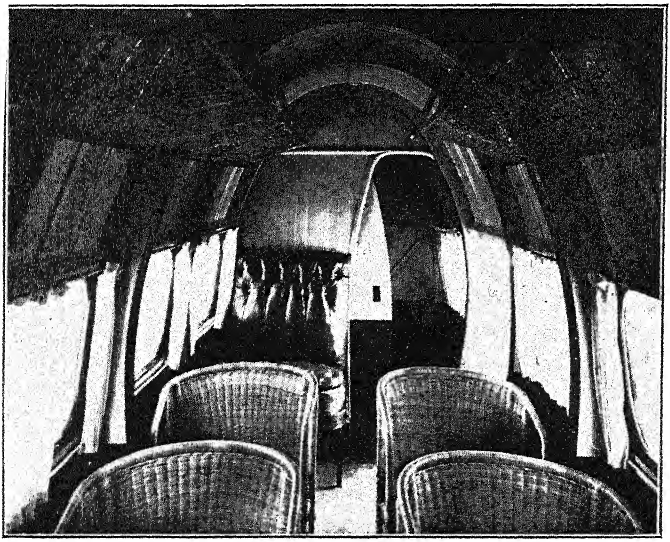
The great air port of London, the Croydon aerodrome, is not only the finest aerodrome in Great Britain, but it is one of the finest in the world. Yet just before the Great War this wonderful air port, with its great air liners flying to and fro like giant insects of some Wellsian dream, was a peaceful scene of agriculture, a quiet spot where cattle grazed and chewed the end of contentment, where golden corn stood ripe in the summer sun.

The coming of the aerial age changed all that. Early in the Great War the Royal Air Force entered those fields, sheds sprang up everywhere, and machines began to fly in and out of the now levelled corn fields.

Then the Great War ceased and Civil Aviation took over. The aeroplanes of War were replaced by the winged messengers of Peace. The offices of various flying companies sprang into existence, the inevitable Customs shed sprang into existence, and even a hotel appeared where intending and arriving air passengers could eat and drink in comfort. The hotel, like all the buildings, is only one storey high, for high buildings are not wanted on an aerodrome. Here, too, intending travellers can sleep over night.



Interior of Junker's Passenger Machine.



Interior of Vickers Vimy Commercial Machine.

PLATE VII.

The Paris air port is at Le Bourget, and is owned by the French Government, who let it out in sections on hire to the various aircraft companies who use it continually.

The aeroplanes arriving and leaving are in charge of the Controller of the Aerial Navigation Service, who endorses the pilot's papers and gives him permission to leave. Each machine is fully inspected before it is allowed to take the air. Each aeroplane on its arrival at Le Bourget taxies along the ground to the shipping platform where the usual customs and passport formalities are observed.

Each aircraft company which uses Le Bourget aerodrome has, as its official quarters, one or two buildings which are fitted with every modern device for comfort. For the comfort of the passengers while in the air port there is a café where refreshments can be obtained. There is a special general repair shop and a shop where engines are overhauled and kept in good running order. The station as a whole is under the control of a superintendent who keeps in constant communication with other French air stations and with foreign air stations, so that he knows not only what aeroplanes are due to arrive at Le Bourget, but when they are due to arrive. The same procedure takes place when an aeroplane leaves Paris. The aerodrome to which it is flying is notified, and upon its arrival Le Bourget is informed. The aeroplane, too, carries wireless, so that it is never out of touch with one aerodrome or another in an emergency, and the pilot can receive instructions about altering his course if necessary, or warnings about weather conditions.

A great naval air port is at present under construction on the banks of the Seine, at the Orly

aerodrome, a few miles above Paris. It is intended to make this one of the greatest air ports in the world.

Since landings are made at night as well as during the day special lighting arrangements are made to allow the aeroplanes to land safely at night. The landing ground itself is outlined with red and white lights, the centre of the ground being picked out with a large circle of light. A large T-shaped structure is lighted up at night to indicate to the pilot the direction of the wind, while a powerful aerial beacon, which can be seen 30 miles away, further facilitates night landing. Searchlights, too, are used to light up the aerodrome. Le Bourget is, in fact, one of the best organised aerodromes in Europe, and one of its main air junctions.

The navigational aids for the pilot on the London-Paris route fall into two categories, and it is interesting to trace out the ground organization already in existence. There will be in operation the following :—

Croydon.—Neon beacon with an occulting light flashing 1 sec., eclipsed 1 sec. Flood lights, Neon ground lights, and obstruction lights.

Tatsfield.—Automatic lighthouse, visibility 30 miles.

Penshurst.—Emergency landing ground. Lighthouse. Visibility 12 miles. Automatic wind tee. Illuminated at night and showing wind direction. Visibility one mile.

Marden.—Small portable lighthouse.

Littlestone.—Emergency landing ground near

the coast. Lighting arrangements duplication of Penshurst.

LYMPNE.—Lympne and Littlestone are alternative costal aerodromes.

For the Channel crossing the ordinary marine lighthouses are, of course, available, with the Verne lightship in mid-Channel as an additional guide and Cape Grisnez and Etaples lights to identify the French coast. Once over the coast the following French facilities will be available by arrangement, though in this case the intermediate navigational lights are not automatic and operate only on request :—

ST INGLEVERT.—Aerial lighthouse flashing Morse code for letter A. Flood lights for landing.

BERCK.—Lighthouse flashing D.

ABBEVILLE.—Lighthouse flashing F.

POIX.—Lighthouse flashing Z.

BEAUVAIS.—Lighthouse flashing G.

LE BOURGET.—Terminal aerodrome with lighthouse and flood lights, obstruction lights, etc.

These landing grounds are about thirty to thirty-five miles apart, and form a chain on the recognized London to Paris route. On a clear night these facilities are adequate, but the pilot needs navigational help when there is a considerable amount of cloud about at any height from 500 feet to 1000 feet. The Vickers vanguard is fitted with all ordinary navigation instruments and cabin lights—its cabin approximates, in fact, to a Pullman car—and it also has the Reid turn indicator.

The latter instrument is an invaluable aid to a pilot in cloud flying, when the absence of any visible horizon makes it exceedingly difficult for a pilot to maintain his machine on a steady and level course; but the pilot also wants to know that he is maintaining his direction. One method is for him to send out a call sign which is picked up by two land stations. It is easy, therefore, to tell the pilot where he was when he first called. A second method is to install in the machine a rotating loop system, with which any known wireless station on the ground can be found. Then the navigator in the machine can find for himself his position without any reference to ground officials. The third system is by the use of wing coils in the machines connected to a balancing apparatus. The pilot wears headphones, and hears, with varying intensity in each ear, the signal being picked up from one directing wireless beacon according to which side he is of the direct path to it. When he is flying straight to it, there is silence in the headphones. This system is the simplest of all for use on regular night flying routes with beacons at selected and terminal points. The pilot can test whether the system is in order by occasionally swinging just off the course and picking up the buzz.

Some half a dozen miles from Amsterdam lies the Schipol aerodrome. There, day after day, circling down from the skies, can be seen the most wide international collection of aircraft to be seen at any aerodrome in the world. There, hour by hour, arrive the great Dutch Fokker monoplanes, the Vickers, De Havilands and Handley Pages of the Imperial Airways; the great French Goliaths and Jabirus; Swedish all-metal monoplanes with blue and yellow tails, and aluminium painted Belgian machines. From

all quarters they come, London, Paris, Brussels, Berlin, Copenhagen, Rotterdam, and other great continental towns, monoplanes, biplanes, wooden aeroplanes, metal aeroplanes, and all types in between; machines with one engine, machines with two, three or four engines, all come roaring down to the line of sheds of the aerodrome. Out step unconcerned passengers who make inquiries of officials to learn the next air connection, or hurry through the customs just as they would if they had arrived at Dover from the cross-Channel steamer.

Between all the great air ports air beacons are being erected so that night flying will be possible. In the future there will be hundreds of these flashing beacons, each with its own distinctive time of flashing, on the main air routes, so that it will be as easy for a pilot to find his way by night as by day. These beacons will be visible from the air from fifty to two or three hundred miles away, so that a pilot never need be out of touch with one or another. Undoubtedly, too, special illuminated signs will be erected which will indicate to the pilot flying near them the direction and strength of the wind.

The aerial lighthouse, for example, which has been erected at Dijon, in France, has a range of three hundred miles. It is situated on the summit of Mont. Afrique and its powerful beams have a strength of a milliard candle-power. The Dijon Lighthouse flashes every five seconds, and even in dull weather the beacon is visible over a hundred miles away.

It will be realized from the brief outline given of the arrangements which have to be made on the ground so that an aeroplane can fly, involve not only a very large expenditure, but require a large staff. The

ground organisation, indeed, is by far the most expensive side of flying, for nothing must go wrong on the ground any more than in the air. The sudden extinction of lights on an aerodrome, the failure of an aerial beacon to flash out its welcome signal, might spell disaster as much as the breaking of a wing in the air. An efficient ground organisation is as necessary, indeed, for safe flying as an efficient pilot and aeroplane are.

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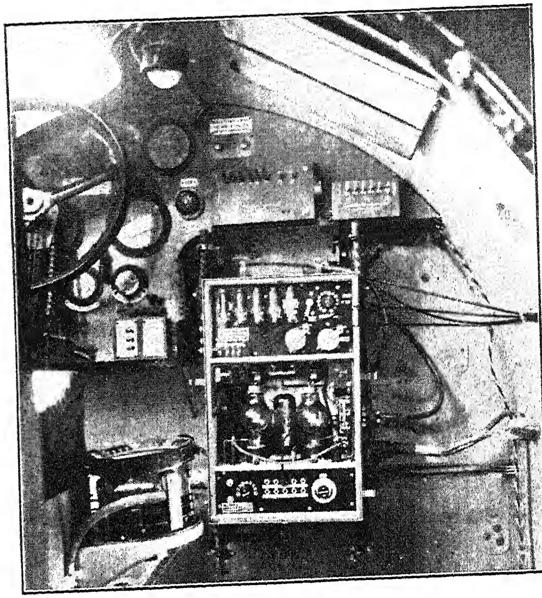
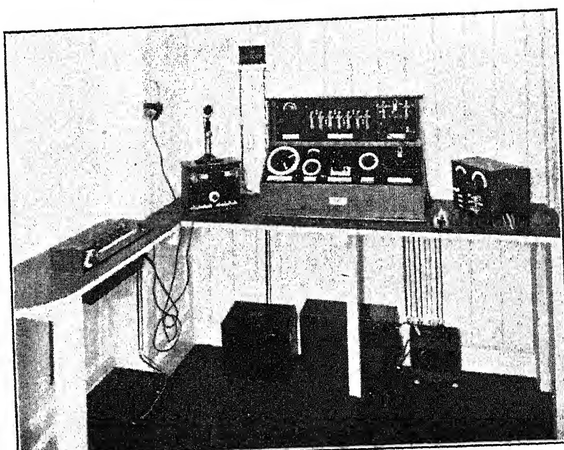


Marconi Aeroplane wireless receiving and transmitting set.



Direction Finder used in Aerodrome wireless receiving station.

PLATE VIII.

CHAPTER VIII

Safety in the Air

It is clear that in some ways flying must be made safer than any other means of transport, for an accident in the air or when landing or rising from the ground is more likely to lead to fatal results than a collision between ships at sea or an accident on the railways. In an accident at sea, for example, at the worst there is always a chance of every one on board being saved by means of boats, emergency rafts and so on, and the insistent S.O.S. call of the disabled ship brings other ships racing to the rescue.

In the case of a disaster in the air, a wing breaking, or a collision, there are no such parallel means of saving life, though methods are being evolved which will enable passengers to come safely to the ground even in the case of a breakage in mid-air. But the most important thing is to prevent breakages in the air, to prevent collisions, and to avoid forced landings in unsuitable country where there is every prospect of disaster.

As the pilot is naturally one of the chief factors in the safety of the air, greater precautions are taken to see that he is always fit than is the case with other forms of transport. Every pilot, of whatever nationality, has to hold a certificate that he is a proficient flyer and that he is medically fit. This certificate has to be renewed every six months, unlike a motor driver licence, and each time the pilot's physical fitness is reconsidered. A motorist might be blind in one eye, have a wooden leg, be suffering from heart

disease, or a hundred and one other physical disabilities, but no pilot would be allowed to fly if he had anything the matter with him. He has to be physically fit all the time, and he is not allowed to fly if he does not keep himself fit. If those in charge of the aerodrome have any reason for thinking a pilot is not fit to fly they can at once refuse him permission to do so. So in this way the first step is taken to ensure the safety in the air. And it is an important step, for upon the fitness of the pilot in every way may depend the safety of all his passengers.

Every aeroplane, before it is allowed to fly and carry passengers, must carry an Airworthiness Certificate, which is a certificate issued by the country to which the aeroplane belongs to signify that the aeroplane has conformed to certain standard minimum requirements of strength and safety. Each machine before it is allowed to take up passengers must go through its flying trials satisfactorily. All the workmanship put into building of aircraft flying for hire, as well as military aircraft, has to be passed, as well as the materials of which the aircraft is built, before it is flown.

The greatest care is taken in the choice of materials for the construction of aeroplanes, as finally everything must depend upon the strength and efficiency of the materials used. All wires have to be of the strength specified for the particular machine being built, all wood must be the best possible, well seasoned, free from any flaws of any kind at all, as knots and so on which make it weaker. So all fabric used to cover the wings, even the dope and glue used, must be up to a certain standard, and it is the duty of aircraft inspectors appointed by the various governments to see that all

such materials used are those specified by the constructors of various forms of aircraft. As a rule in every aircraft factory there is a resident government inspector who can examine an aeroplane or flying boat in every stage of its making and so make sure that all the proper materials are being used. The British Engineering Standards Association for Great Britain issues many specifications of materials used in aircraft, wood, steels, alloys and so on which enable aircraft constructors to use the best materials available. Many forms of construction have been made standard, as steel tubes and streamline wires, so making the inspection of workmanship and materials an easy one.

Not only are specifications issued of the best materials to use together with a full description in many cases of how to use these materials and get the best results from them, but many governments are continually carrying out tests in their national laboratories of particular forms of construction, of particular materials and so on, and the results of these tests are published for the information of all aircraft constructors.

Every step in the making of an aeroplane is overlooked by experienced men, from the first approval of the drawings of the aeroplane until it is finally completed, built and ready for its flying tests. Every bolt and nut, every fitting, every wire, the controls, the engine and propeller, every part indeed from the smallest to the largest, is carefully inspected and passed by trained mechanics and engineers, and it is rare nowadays for an aeroplane to break in the air due to the failure to put in the right material of the proper strength. As explained later in this chapter, often a complete aeroplane or parts of an aeroplane

are specially tested in other ways to make assurance doubly sure. Most aeroplane engines are tested, too, for at least twenty-four hours continuous running before they are fitted into an aeroplane.

At the National Physical Laboratory in Great Britain, and at similar institutions in other countries, small models of aeroplanes and also parts of aeroplanes are tested in various ways to ensure the safety of the complete aeroplane. At such institutions are large wind tunnels. These wind tunnels are so constructed that a current of air, varying from a gentle breeze to a violent gale of wind, can be passed through them. A model of an aeroplane is suspended in the tunnel and its behaviour watched. In this way some idea is obtained of the way the real aeroplane will behave when it is flying in the varying kind of weather it will meet with. Various kinds of wings are put in these wind tunnels and tests are made to find out how they lift, various shaped parts of an aeroplane are put in these tunnels to find out what resistance they offer, and so on, so that long before an aeroplane is actually built the way it will fly, the speed at which it will fly and other things about it can be very accurately predicted. It is only by carrying out a series of tests like this, indeed, that the performance of an aeroplane can be built, for it would obviously be much too expensive to build aeroplanes and test them and destroy them if they are not exactly what is required.

Having made sure as far as possible that the aeroplane will be safe in the air in normal flying there is always the possibility of disaster due to fire, collision, landing or getting off from the ground. Many disasters have happened when the aeroplane is just getting off,

largely due to the aeroplane rising at too steep an angle or not quite fast enough, but the majority of this kind of accident can now be avoided due to the greater skill of pilots and the greater knowledge which has been acquired of the causes of disaster. The Bramson anti-stalling gear, described later in this chapter, also makes the chance of disaster when rising or landing very much smaller. The Handley Page slotted wing, a special kind of wing which can be opened or shut rather like a venetian blind, allows an aeroplane to rise or land more slowly, and of course the chances of a fatal accident are considerably lessened as the speed of any crash decreases. The time will come when aeroplanes will be able to leave the ground or land at only twenty miles an hour and then, even if there is a crash, it would probably not be a very serious one. Various new types of wings and even new types of aeroplanes are being experimented with to reduce these speeds to the very lowest possible.

The chances of fire in the air are very small. In many aeroplanes fireproof bulkheads are placed between the engine and the body of the machine, and the petrol tanks are placed well away from the engine to minimise the risk of fire. The chief danger from fire is actually in a crash, due to a spark from one of the electric leads, and this is now largely eliminated by keeping the electric leads away from the vicinity of the petrol supplies. The all-metal machine of the near future will do away with all danger of a fire spreading in any case.

Parachutes add to the safety of passengers in the air, and automatic parachutes have now been invented so that a passenger has nothing to do but jump head-

long out of the machine to land safely, when the aeroplane is, of course, at least a hundred or more feet above the ground so that the parachute can open. Such parachutes are fastened on to the backs of the passengers and open out automatically. The modern parachute is the lifebelt of the air.

Collisions in the air are very rare, and most of those which have happened have been due to manœuvres in military machines, when the special regulations for avoiding collisions in the case of civil aircraft are not insisted upon. There are certain rules which aircraft must observe when flying and meeting or overtaking other aircraft, just as there are rules for motor cars on the road. These rules are agreed to by most nations, so that a pilot has only one set of air traffic regulations to remember, no matter what country he may be flying over.

First of all any flying machine must give way to any balloon or airship. When two aeroplanes are approaching one another and are likely to pass so close that there is danger of collision each aeroplane must alter its course to the right. If two aeroplanes are flying on routes which cross one another, then the aeroplane which has the other on its right hand side must keep out of the way of the other. These and similar regulations make the chances of collisions in mid-air for civil aircraft practically negligible. Aeroplanes arriving at an aerodrome must get permission from the officer in charge of the aerodrome to land, either by wireless or by signals, so that they shall be in no danger of crashing into another aeroplane just about to rise from the aerodrome, or into an aeroplane on the ground which the pilot may not have seen.

At night aeroplanes have to carry lights just as vessels on the surface of the sea do. Every aeroplane must carry a white light in front and a white light in the rear or on its tail. On the right-hand plane a green light must be carried and on the left-hand a red light, so that they can clearly be seen from each side in turn. These lights must be so arranged that the green light cannot be seen from the left side of the aeroplane or the red light from the right side. So when two aeroplanes are passing at night each should see the other's green light as they pass. When landing at night at an aerodrome permission must be obtained by telephone or by signals. The signal from the aerodrome is usually given by the firing of a green Very's light, or the flashing of a green lamp. If a red light is shown from the aerodrome it is a warning to the pilot that he is not to land. As explained in another chapter, on the great air routes there are aeroplane beacons and ground lights which guide the aeroplane on its way at night and special devices to enable the aeroplane to land in a fog or in misty weather.

All aeroplanes carry certain instruments which give the pilot valuable information. One instrument, for example, tells him at what height he is flying, and another tells him at what speed he is flying through the air, a very important thing to know, especially when he cannot see the ground owing to fog, for if his aeroplane flies too slowly it will drop suddenly with the consequent risk of disaster. Compasses and maps enable him to find his way across country. The maps used are not like ordinary maps, but show the appearance of the country as it is seen from an aeroplane, picking out all the important landmarks which will

serve the pilot as a guide, and telling him where there are suitable landing places and aerodromes. Other instruments tell the pilot what oil and petrol he has in his tanks, how fast the engine is running, and so on.

Finally, when a machine is built, most firms ask a pilot to fly it and put it through its paces, before it is used for actual passenger flying. There are many famous pilots who carry out these tests, and are known as test pilots.

Among the many ingenious devices for ensuring safety in the air one of the most ingenious is that known as the Bramson-Savage anti-stall gear. This was successfully demonstrated in September 1925. Briefly an aeroplane is said to stall when its flying speed becomes too low for the wings to support it in the air. When an aeroplane stalls there may be a sudden earthward plunge with the resultant crash. Many accidents have been caused by a machine stalling, indeed. If a pilot is compelled to make a forced landing, for example, in his anxiety to choose a good landing ground he may momentarily allow the machine to stall and the Bramson-Savage anti-stall device warns him that his machine is flying too slowly.

Briefly the gear is attached to the joy stick or control column of the machine, and when the angle of the wings becomes too great to the air so that the aeroplane is in danger of stalling, the gear jerks the joy stick forward, and so depresses the nose of the machine by raising the tail. The jerking of the joy stick forward serves as a reminder to the pilot of his danger, if he has been occupied with other things. The anti-stall gear is undoubtedly an important advance in ensuring safety in the air.

Another method of keeping control is by means of a gyroscopic mechanism which controls the movements of the rudder and the ailerons, so that the pilot can keep the aeroplane on an even keel without constant attention to the effects of gusts and the like.

One of the most interesting and one of the least-known methods of ensuring the safety of aeroplanes in the air is by means of the destruction test on the ground. In a destruction test a full-sized machine or a part of one is actually broken up under certain conditions to see how it would have broken in the air.

The way an aeroplane is tested is roughly as follows: The aeroplane is first of all turned upside down, and then special flat bags of shot are placed on the planes little by little until the planes give way. The weight of the bags of shot are known, so that the total weight the wings will bear before they break is known. When an aeroplane is flying horizontally the forces acting on the wings are nearly exactly equal to the total weight of the aeroplane. When an aeroplane breaks, therefore, under the weight of the shot bags, it is a simple thing to calculate how much stronger the wings are than is necessary for flying horizontally. The wings may be anything from four to seven times as strong as necessary, and if horizontal flight were all that mattered the wings could be made very much lighter than they are.

But an aeroplane, like a motor car, has to turn corners, and unlike a motor car carry out many other evolutions, like nose-diving, climbing, flying upside down and so on. If a motor car turns round a corner quickly a big strain is put upon the axles and the

chassis frame, and in the same way if an aeroplane turns quickly, or flattens out of a nose dive quickly, big strains are put upon the framework of the wings. If the wings are not made much stronger than is required for simple horizontal flight they would crumple up and the machine would crash to the ground. Even with the big passenger aeroplanes which do not stunt in the air, which fly most of their time horizontally, they have to fly in all sorts of bad weather, and gusts and the like all put strains upon the framework.

Testing aeroplanes to destruction this way not only finds out if the framework of the wings themselves is weak, but it finds out if the wires used are weak, or the metal fittings which are used to fasten them to the framework.

Not only are complete aeroplanes tested in this way, but also all parts of aeroplanes, as the control surfaces, the ailerons, rudder, and elevators. It might be quite possible to break any of these surfaces by jerking them into action too violently and so their exact strength is important to know, so that pilots or designers will also know how far they can go with safety. Of course the strength of any part of an aeroplane can be calculated mathematically, but though this is satisfactory up to a point, unexpected weaknesses may be revealed by actually breaking the wings. Moreover the mathematics of the aeroplane receives confirmation by these tests, which help to show where the theory is accurate and where it is not. In all these tests the shot bags are loaded on the wings to imitate as far as possible the known air forces on the wings.

The fuselage of an aeroplane is tested in much the same way as the wings, especially the rear and forward

parts of it where the tail and main planes are attached, as these are points which are often strained severely in flight. Special twisting tests are given to the fuselage as well, as there is always a tendency for the body of the machine to twist in certain manœuvres.

Even the undercarriage is tested in this way, to see it is strong enough for the aeroplane to land under all conditions. Landing at high speed on rough ground always strains the undercarriage, and if it were broken the aeroplane might pitch forward on its nose and crash. In testing the wheels of an aeroplane the whole undercarriage is dropped from varying heights to find out what strain they will actually stand.

Flying in the dark is not difficult. In fact if a pilot can see the stars it is no more difficult in many ways than it is to fly during broad daylight. But it is landing in the dark, landing in foggy, misty weather, which is the great drawback to all night flying. Once it has been made possible to land in the thickest fog and on the blackest night and to land as safely and surely as it is in full sunlight, then aeroplanes will fly as regularly day and night as express train services speed across country. Moreover the aeroplane will not be handicapped by fog to anything like the extent that the railway engine is. For the greater part of the journey the aeroplane is able to rise above the fog, to fly in clear weather, and it need only be in fog at the few moments it takes to rise above it or land below it.

The efforts of all those in charge of regular flying services have been directed towards two things above all others, reliability and safety. Reliability is easily obtainable once safety is fully attained and already

the reliability is of an extremely high order. Aeroplane engines have reached such a high state of perfection that they rarely fail in the air, and it is very bad weather indeed when an aeroplane is unable to fly, so bad indeed, as a general rule, that the cross-Channel sea services have to be suspended. And much of the reliability now depends upon the ability of a machine to land and to land safely, or to get off safely when the ground cannot be seen many feet up.

In the early days of night flying, buckets of blazing petrol were used as ground flares for landing. This method was crude, often unsatisfactory, and did not give the pilot that confidence which he should have. Now it is as safe to land in the dark, provided there is no fog, as it is to land in daylight.

One of the most ingenious methods of guiding an aeroplane safely to the ground is by means of the Loth leader cable. This method works on a system by which a powerful electric current is passed through it and the magnetic field set up is made to affect a very sensitive device in the aeroplane. By means of the Loth cable, signals can be sent to an aeroplane three miles away, flying 2000 feet high. The cable acts as a guide to the aeroplane which is thereby able to fly above it and along it, the instrument carried in the aeroplane telling the pilot what height he is above the cable, which is laid just below the ground. By the middle of 1925 a number of these cables were put down between Paris and the coast and many others were in contemplation at the great aerodromes.

The aerial lighthouse is another great step forward in making flying at night safe. The aerial lighthouse

differs from the ordinary lighthouse in many ways. First it indicates safety instead of danger. Secondly the aerial lighthouse throws much of its light on the ground near it. At Croydon a great Neon red-flash gas lighthouse has been installed which forms a guiding beacon for an airman many miles before he reaches his destination. Illuminated wind indicators show the pilot on many aerodromes exactly which way the wind is blowing so that he can land up wind, and therefore more safely.

Actual night flying is in operation in many places. A night air mail, for example, is carried between Chicago and New York, the distance of nearly 1000 miles being covered in nine hours. The distance is covered entirely at night and five ranges of mountains have to be crossed *en route*. Each aeroplane carries 250,000 candle-power headlights, and the route between the two cities is marked out by 56 flashing beacons and flood lights to illuminate landing fields in case of emergency.

Night flying is being arranged for on the London to Paris route and will soon be in regular operation, and other night flying routes are being opened on the Continent. Flying at night, indeed, will soon be as common as the running of express trains at night. A recently invented safety device, especially for night flying, is a form of gyro-operated rudder and gyro system of aileron controls. By this new system the pilot will be able to set his aircraft to fly automatically upon any given course, and will simply vary the height at which he is flying by altering his elevator controls and adjusting his engine speed.

Of the many inventions which have proved their value for making the air safe perhaps the one deserving

of most praise is wireless. Wireless enables a pilot to keep in touch with the ground from the beginning of his flight to the end, to receive instructions from those in control of great aerodromes, to obtain the latest information about the weather and other valuable news which may mean all the difference between safety and disaster.

In the Control Tower at Croydon aerodrome sits a wireless operator who is able to keep in touch with any machine not only approaching the aerodrome but a hundred or more miles away if necessary. The modern high powered passenger machine is fitted with a transmitting as well as a receiving apparatus so that the pilot can not only hear what the operator in the Control Tower has to say, but he can talk to the operator and ask for any information he wishes or report when he is passing over certain definite landmarks.

It is part of a pilot's duty to tell Croydon, say, when he is over certain places when flying to the Continent. This enables the Traffic Officer at Croydon to mark on a large map with flags the position of every aeroplane at a given moment, whether approaching or leaving the aerodrome. If he sees that two machies are approaching at approximately the same time the Traffic Officer can warn each pilot, direct him what route he shall take, and thereby prevent any chance of a collision.

An ingenious use of wireless for safety purposes is to enable a pilot to find his way if he finds himself lost in the air, a thing he can quite easily do if he runs into very bad weather or over a thick fog which completely hides the ground from him. The way the pilot finds his way is as follows:—

He calls up Croydon and tells them he has lost his way, at the same time giving them the number of his machine and asking them if they can tell him where he is. The operator at Croydon immediately calls up the wireless station at Pulham in Norfolk, and the pilot of the lost aeroplane is asked to talk for a few minutes while Croydon and Pulham both listen to what he has got to say. Both these stations have direction finding aerials and by means of these aerials they are able to say from which direction the voice of the pilot comes. The Pulham operator tells the Croydon operator from which direction the pilot is speaking and the latter has only to draw two lines on a map, that giving the direction from Pulham and that giving the direction from Croydon. Where these two lines meet is where the aeroplane is flying, and the pilot is promptly informed and told in which direction to fly to reach the aerodrome. If necessary he can so obtain his position a number of times before he lands.

There is no need for a pilot to know anything about the Morse Code or to be a wireless operator as all communication is carried out by telephone from most of the big passenger planes. The wireless set used, a Marconi set, has a range of from 100 to 200 miles and works on a wavelength of about 900 metres. The current required to work the transmitting part of the set is provided by a generator driven by a small propeller usually fitted beneath the front part of the fuselage. The aerial used is a single-wire aerial, about 200 feet in length. It is, when not in use, wound on a winch. When required the aerial is allowed to run out below the machine, being weighted at the end by an iron ball.

Listening to pilots communicating with Croydon, however, will often be like listening to some foreign jargon, or a jumble of meaningless phrases which leave the average listener in bewildered. Certain abbreviations and certain words are always used in order that there shall be no possible chance of mistake as to the meaning of the message. A pilot cannot afford to make a mistake. He must play for safety every time, for he has many others to consider on board.

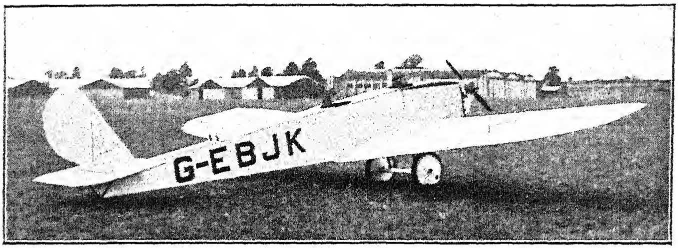
"Hullo, Croydon, Imperial Uncle Beer calling, now passing Biggin Hill. Over!"

That is what Croydon might hear, and the operator would know that one of the Imperial Airways machines with the final identification letters U.B. was passing over Biggin Hill aerodrome. The final word "Over" tells the Croydon operator that the pilot is switching his transmitting apparatus over to receiving so that he can hear what Croydon has to say.

One of the least frequent calls of an air pilot nowadays is the May Day call. This call is the aerial S.O.S. and is given by a pilot when he has to make a forced landing. He also gives his position so that assistance can be sent out to him as quickly as possible. The May Day call is really an adaption of the French *m'aidez*!

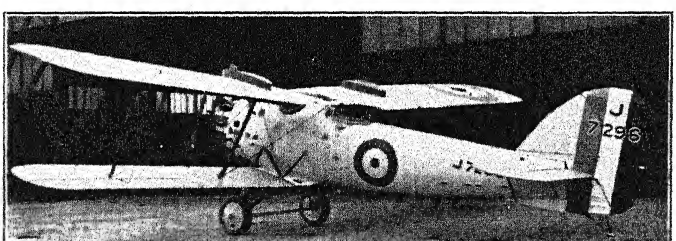
Movements of all aeroplanes are reported from one aerodrome to another, Thus if an aeroplane flies from London to Paris, Croydon tells Le Bourget, the Paris aerodrome, that such and such an aeroplane started at such a time. When the aeroplane lands at Le Bourget, its safe arrival is reported back to Croydon.

So every minute it is in the air not only the pilot is doing his best for the safety of his passengers, but



Bristol Brownie Monoplane.

Avro Light Aeroplane.



Short Springbok.

PLATE IX.

all kinds of people on the ground are on the look-out so that the great machine flying overhead shall be as safe and, indeed, safer than the modern express train. Every precaution which human ingenuity can devise is taken to make the air as safe for man as it is for birds.

CHAPTER IX

Types of Aeroplanes and Seaplanes

Just as there are many different kinds of motor cars, sea-going vessels and trains, so in the newest form of transport there are many different kinds of aircraft.

Roughly, aircraft may first of all be divided into two main classes, (*a*) lighter than air, and (*b*) heavier than air. With the former—balloons and airships——we are not concerned in this book.

Heavier-than-air machines may, for convenience, be divided into many different classes, and it will be convenient to consider them in three main divisions: (1) military, (2) goods and passenger and (3) pleasure and sport. Each class is itself divisible into aeroplanes, seaplanes, flying boats and amphibians.

Aeroplanes are those aircraft made to rise from and land on the ground; seaplanes and flying boats rise from and land on water; and amphibians are equally at home on land or water. It is impossible in a book of this size to do more than outline a few of the various types of aircraft. In various other chapters some of these types are described at greater length, as well as their functions.

Military aircraft consist chiefly of flying scouts, reconnaissance machines and day and night bombers, each with their own particular characteristics. Fighting scouts are fast single or two-seater aeroplanes, armed with machine guns. They can climb rapidly to great heights, can manœuvre in the air with great ease, and are concerned chiefly with fighting similar machines of the enemy. On such machines everything, as far

as possible, is sacrificed to speed and manœuvrability. On them depend very largely the successful aerial offence and defence of a country. They are the first line of attack and defence, and serve as escorting machines when necessary for day and night bombers and the like.

At the beginning of the Great War the Vickers Fighter F.B. 5., fitted with a 100 horse-power monosoupape engine, was the only definitely offensive aeroplane in existence. No special attention had been paid to the arming and design of aircraft for war purposes, though it had been widely recognised that aircraft would have to be designed exclusively for war needs. Aeroplanes were in existence for bomb dropping and reconnaissance work, but fighting in the air, as developed during the Great War, did not exist. The Vickers F.B. 5., or Vickers Gun Bus, was a machine of the pusher type, that is to say, the air screw was behind the main wings. This enabled a machine gun to be mounted in the nose of the fuselage with a clear field of fire. It was impossible in those early days to fire through the propeller without damaging it. This was only made feasible later on in the war, when the remarkable synchronising gear was attached to machine guns which only allowed them to fire when a blade of the propeller was not passing the muzzle of the gun. The Vickers Gun Bus was a two-seater biplane and remained in commission till as late as March 1916, when other types of fighters began to supersede it.

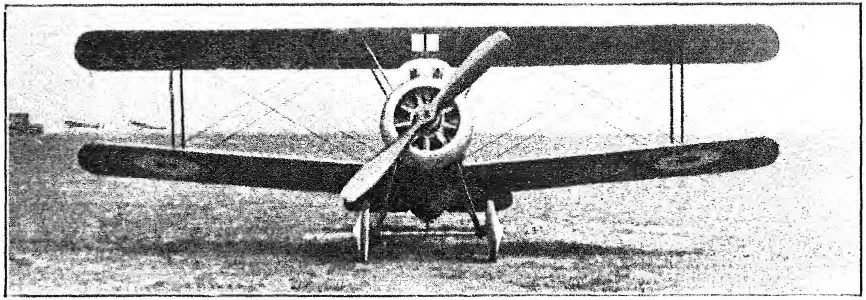
In the chapter on aeroplanes in war some of these fighters are more fully described. In the early days of the Great War speeds of 70-90 miles an hour were considered to be very good. By the end of the war speeds of 120-140 miles an hour were being reached

and higher speeds still were being contemplated for fighting scouts; speeds of close on 170 miles an hour are, indeed, now reached by American scouts. The Martinsyde A.D.C. 1., produced in 1924, for example, has a maximum speed near the ground of 163 miles an hour, and 154 miles an hour at 10,000 feet. It can climb to a height of four miles in about eighteen minutes.

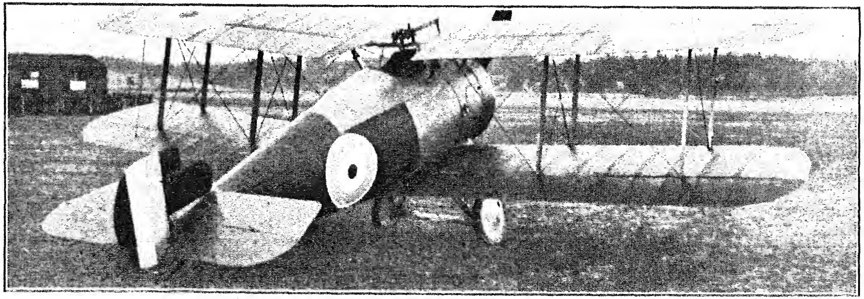
This machine is a single-seater fighter fitted with a 380/425 Armstrong-Siddeley Jaguar engine and carries two Vickers machine guns, 1200 rounds of ammunition, and enough petrol and oil for two and a half hours. It weighs a little over a ton fully loaded.

The Mars VI and the Grebe, both productions of the Gloucestershire Aircraft Company, makers of many famous racing machines for the Aerial Derby and the Schneider Cup, are two other high-speed, single-seater fighters. Petrol tanks are built into the upper wings of these biplanes to reduce resistance as much as possible. The Hawker Woodcock, made by the successors to the Sopwith Aviation and Engineering Company, the constructors of the well-known Camel, Pup, Snipe and other fighters, is a single-seater scout biplane fitted with a Jupiter radial engine. Here, as in the case of most military machines, it is not possible to give any details, as it is a machine in use by the Royal Air Force.

The Siskin, a similar machine produced by Armstrong-Whitworth's, is an all-steel machine, and normally carries two guns with 2000 rounds of ammunition. A third gun can be carried if required. Essentially, indeed, all flying scouts are built very much on the same lines, and what one machine gains in one way another gains in another. It is not possible to design



Sopwith Camel : a famous fighting machine.



Sopwith Snipe.

PLATE X.

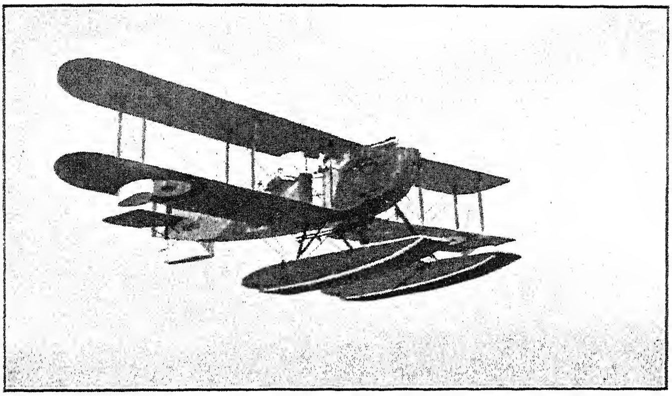
any machine which will satisfy all the requirements of the military authorities, as these requirements are bound to clash in many ways with general aeronautical design considerations. For example, in the ideal fighting machine the pilot, or his observer if the machine is a two-seater, should be able to see in any direction from his seat. But the planes themselves, the tail plane, and the fuselage, all obstruct the view in certain ways. The pusher type of machine, in which the pilot sat in the very nose of his aeroplane, afforded an excellent view in most respects, but that view downwards and backwards was obstructed by the wings of machine, so that an enemy might approach from behind without being seen. The problems of view of a good field of gun fire have always been difficult ones, and a compromise has to be effected.

Then, again, an aeroplane should carry as little superfluous weight as possible if it is to have high speed and great manœuvrability. But the military authorities want as much as possible carried, guns, ammunition, wireless, and so on, which add to the weight and so detract from the performance. Machines have to be designed, too, to give their best performance not necessarily on the ground, but at a height of 10,000 feet or more, where they will be called upon to fight. At great heights, specially electrically heated clothing, oxygen apparatus, apparatus for boosting the engine and the like have to be carried, and it is only by skilful design that machines are able to reach the ever-increasing speeds demanded for military purposes.

Reconnaissance machines have to have very similar qualifications to those of fighting scouts. They are often no more than two-seater fighting scouts told off

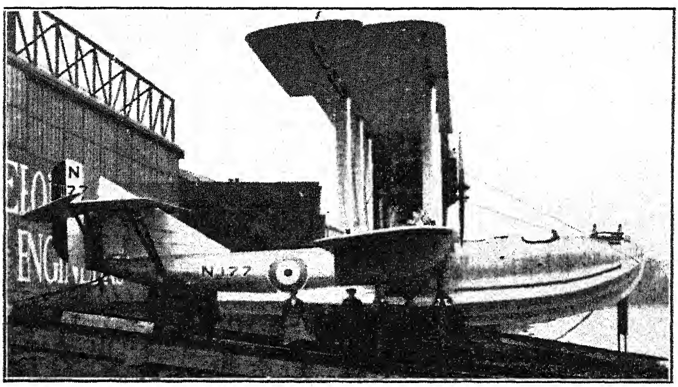
for special work. Such machines are the Armstrong-Whitworth Ajax, the Bristol Bloodhound, made by the Bristol Aeroplane Company, the Vickers Vixen, and so on. With most two-seaters dual control is fitted, so that an aeroplane can be flown from either seat. This type of aeroplane, for that reason, is also largely used for training purposes. The Avro 504 type, the most famous training machine in the world, is fitted with dual controls in this way. Reconnaissance machines usually carry two or more machine guns, wireless and so on. On the Bristol Bloodhound, for example, two synchronised Vickers guns and 1200 rounds of ammunition, one Lewis gun and ammunition, a wireless receiving set, oxygen supplies and electric heaters for the Vickers gun and crews are carried. The Bloodhound is entirely of metal construction, with the exception of the fabric covering of the wings. The all-metal machine will, in a very short time, be the only machine in use in the Royal Air Force ; and there is little doubt that for civil aviation purposes, too, the days of the wooden machine are rapidly coming to an end.

For reconnaissance or spotting work with the Fleet special machines have been designed, machines which can land on the deck or in the sea. Such machines, too, need to have as low a landing speed as possible, on account of the comparatively short run they can obtain on the deck of the ship, and at the same time be highly manœuvrable at low speeds. Some of these machines are flying boats or amphibians, described later. The Blackburn fleet spotter, for reconnaissance work and for spotting gun fire from ships, is fitted with a 450 horse-power Napier Lion engine, and is constructed for landing on deck. The Avro Bison is another machine used for spotting work with the Fleet, and is specially



The Fairey IIID Seaplane in flight.

The Vickers Vanguard 20 seater.



Short F5 Flying Boat with all-metal hull.

PLATE XI.

designed for alighting on or rising from the deck of a ship.

Bombing machines are usually considerably larger than fighting scouts and reconnaissance machines, though the latter are often used as bombers. But the long-distance day and night bombers must be machines capable of flying long distances and carrying heavy loads.

One of the earliest of the big bombers was the Handley Page 0/400, described elsewhere, a machine extensively copied by the Germans with their Gothas and used to bomb London. Since that time many long-distance bombers have been built with a radius of action which runs into over 1000 miles in many cases. One of the most famous of these bombers is the Vickers Vimy, which has, as a commercial machine, carried out very long-distance flights, including those of crossing the Atlantic, flying from London to Australia, from London to South Africa and so on. Since 1918 the Vickers Vimy has been one of the standard bombing machines of the Royal Air Force. It is fitted with the Rolls-Royce Eagle engines, and carries about 1000 lbs. of bombs, as well as three Lewis machine guns and 1500 rounds of ammunition. When fully loaded the Vimy weighs 12,500 lbs., and has a speed of 100 miles an hour near the ground.

The Vickers Valparaiso is a two-seater tractor biplane which is used for bombing and reconnaissance work. It can be fitted with floats or the ordinary land chassis. It is a little less than half the weight of the Vimy, but with a considerably greater speed, 127-130 miles an hour at ground level.

The Virginia is a long-distance heavy night bomber, weighing 16,600 lbs. when fully loaded and carrying a

ton of military equipment and bombs. It is a four-seater, accommodating a pilot, navigator and two gunners, and carries two Vickers machine guns and 1000 lbs. of bombs. The Virginia has a maximum speed of 105 miles an hour near the ground, and is fitted with two Napier Lion engines of 450 horse-power each.

The Fairey Fox and the Fairey Fawn are both bombers and reconaissance machines, the former a two-seater and the latter a three-seater. Both machines are largely used in the Royal Air Force, so that detailed descriptions of them cannot be given. The Fawn is fitted with a Napier Lion engine and has a very wide speed range. It is very largely of metal construction. Its petrol tanks are placed on the top of the upper main plane.

The Handley Page W. 8 is a heavy bomber fitted with two Napier Lion engines. This machine weighs some six tons when fully loaded. Bigger bombers still, which will carry a ton or more of bombs, are under construction. The Bugle, built by Boulton & Paul Ltd., is largely an all-metal machine for use as a bomber. It is a twin-engined machine. It is a three-seater machine, and the fuselage has a gangway, so that the pilot, gunner and observer can quickly communicate with one another. The weight of the Bugle, fully loaded, is about four tons. The remarkable fact about this bomber, as with all machines built by Boulton & Paul, is the all-metal construction. The chief metals used are duralumin and steel.

One of the latest types of bombing machines is the Horsley, built by the Hawker Engineering Company, the head of which is Mr T. O. M. Sopwith, the constructor of such famous flying machines as the Camel

and Snipe. This bomber, which is fitted with a 650 horse-power Rolls-Royce Condor engine, has a speed of 100 miles an hour at 20,000 feet. The Hedgehog, a three-seater reconnaissance fighter, is another product of the firm.

The Avro Aldershot and Aldershot Cub are both powerful bombers built by the Avro firm. The latter machine was fited with a Napier Cub engine of 1000 horse-power, and was for a long time the highest powered single engine aeroplane in existence.

It is a natural conclusion that the aeroplane will serve not only for its primary function of fighting, scouting and bombing in the next war, but that it will act as a transporter of troops. The day is not far distant, indeed, when whole regiments will be moved bodily by air, together with their equipment, so that they can take part in surprise attacks, or can act as reinforcements at critical points in a battle line a hundred or more miles away. The tactics of combined air and land fighting are as yet difficult to foresee, but the transport of troops, munitions and even heavy guns will certainly be part of the scheme of things in another war.

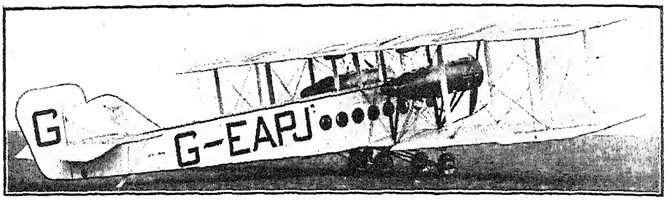
Troop carriers are already being built. A good example is the Vickers Vernon, an adaptation of the Vimy machine. This is a fourteen-seater and it has already been used on a considerable scale as a troop carrier in Iraq. In 1924 the Vernon was employed in the disturbances at Kirkuk. Within a few hours of the receipt in Baghdad of the news that there was trouble, a company of the Inniskillings had landed on the spot and entirely prevented any spread of the disorders.

The Victoria, also built by the Vickers firm, will

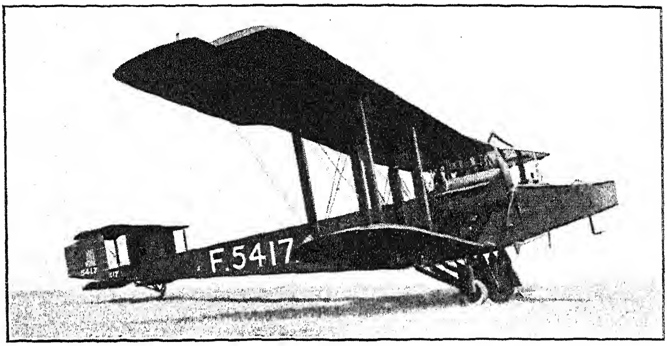
transport twenty-five troops with their equipment and machine guns, in addition to two pilots. It weighs a little over eight tons fully loaded and can fly at over 100 miles an hour. It is not difficult to imagine how an effective fighting force can be concentrated a hundred miles from headquarters in a few hours by means of a fleet of these huge carriers—and they are by no means the last word in troop carriers. The Victoria has a span of over 86 feet and a range of 400 miles.

The Armstrong-Whitworth Awana is a troop carrier with accommodation for twenty-five men and their equipment. The fuselage is built of steel. Fully loaded, the machine weighs eight tons and is driven by two Napier Lion engines.

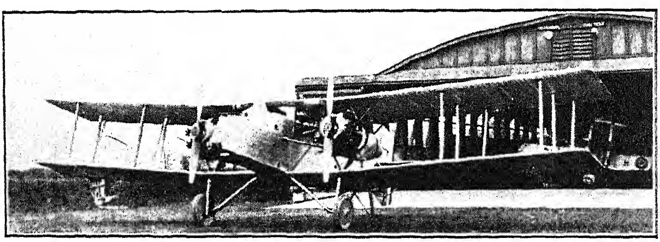
Among special machines designed primarily for the Royal Air Force must be mentioned the various ambulance aircraft. The Fairey seaplane III D has already been mentioned in this connection for its work in British Guiana. The Vickers Vimy and Vernon have also been converted into ambulance machines with accommodation for stretcher patients and their attendants, together with all necessary emergency medical stores, fresh water and so on. The Avro Andover, built for the Air Ministry for operations in Iraq and Egypt, is another ambulance machine, the circular fuselage having hollow walls to keep the temperature of the cabin more even. It is fitted with a Rolls-Royce Condor 650 horse-power engine, can carry seven people, and can make a 700-mile non-stop flight. The Bristol Brandon accommodates two stretcher cases and four seated patients. A special entrance to allow stretchers to be placed in the fuselage is arranged for. All these machines bear on



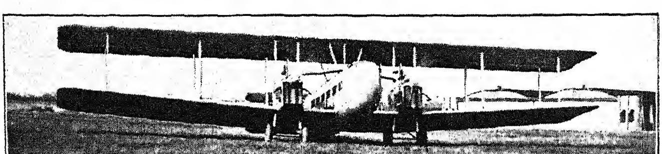
Handley Page Twin-engine Passenger Aeroplane.



Handley Page Twin-engine Bomber.



Boulton and Paul's Bugle.



Vickers Victoria 24 seater troop carrier.

PLATE XII

them the distinctive red cross which marks them out as being ambulance machines. These machines will be developed on a larger scale in the future and will be invaluable for rushing dangerously wounded patients to base hospitals far from the area of fighting. Their usefulness has already been proved in minor ways since the Great War.

Of the many types of aircraft which the Fairey Aviation Company have produced, the Fairey III D seaplane is perhaps the best known. This machine was originally designed for the Royal Air Force, for service with the Fleet, for bombing, reconnaissance, gunnery and general work, but it has also been very largely used in civil aviation. It is a Fairey III D seaplane which has been much employed in British Guiana for the conveying of fever patients to hospital. The nature of the country is such that the journey by land and water takes about seventeen days. By air it occupies only two hours. The flight by Wing-Commander S. J. Goble round Australia in 1924, a distance of over 8500 miles, was carried out in a Fairey III D, and this seaplane is now used by the R.A.F. as the general standard service seaplane.

It is a twin float biplane fitted with a 450 horsepower Napier Lion engine, and has a top speed of 102 knots when carrying a useful load of 1600 lbs. plus petrol and oil for six and a half hours. It has a range of 460 sea miles and can climb to 19,000 feet. The floats are easily detached and can be replaced by a wheeled chassis, so converting the machine into a land plane. The Fairey III D seaplane is a three-seater, carrying pilot, gunner and wireless operator. It is fitted for bomb dropping in addition, and can also be converted quickly for carrying a torpedo.

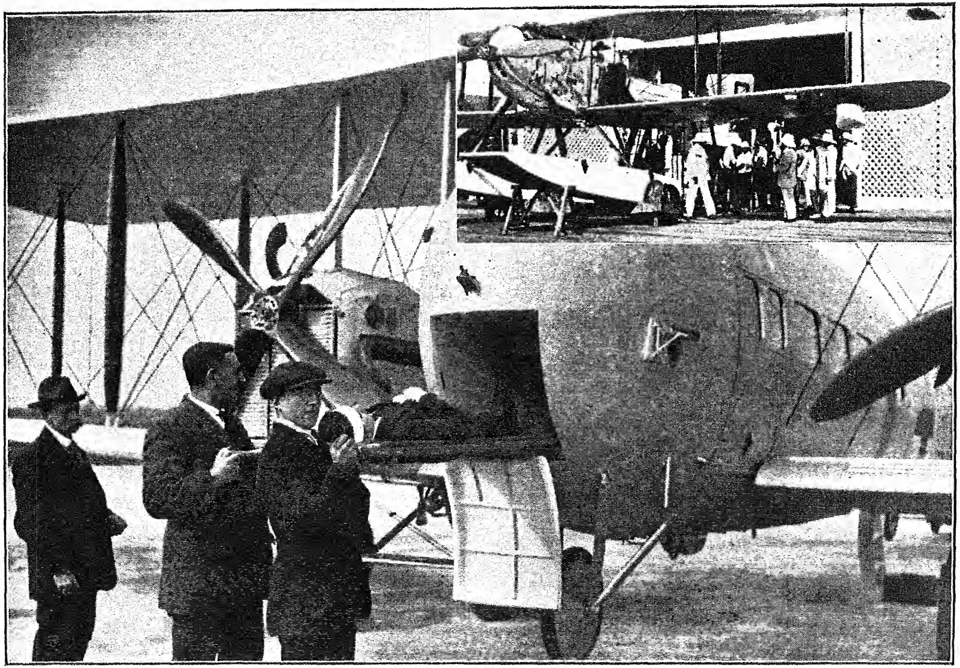
The wings fold so that the machine can be stored on a seaplane carrier in a comparatively small space. Like all the Fairey machines, it is fitted with a patent variable camber gear, so that the lift of the wings can be altered at will by the pilot.

The Fremantle is another type of seaplane built by the Fairey Company. It has a Rolls-Royce Condor engine of 650 horse-power and a petrol capacity for a non-stop flight of 1200 miles. The petrol is in tanks placed inside the floats, and the machine carries a crew of five at a speed of 100 miles an hour. Sleeping accommodation is provided, with a special heating installation.

The Gloster seaplanes, made by the Gloucestershire Aircraft Company, are famous for their flights in connection with the Schneider Cup. The Gloster II entered for the race in 1924 but unfortunately crashed during its trials. It is remarkable for the way every possible part is streamlined in shape, so that the resistance is reduced to a minimum. The Gloster II is a modification of the Gloster I seaplane which won the Aerial Derby in 1923 at an average speed of 192·4 miles per hour over a 200 mile course, reaching speeds of 220 miles an hour along the straight. It weighed a little over a ton and was fitted with a 450 horse-power Napier Lion engine.

The Blackburn seaplanes are very well known. The Swift is a torpedo-carrying seaplane for work with the Fleet. It carries an 18-inch torpedo weighing 1500 lbs., and when fully loaded weighs nearly three tons. It is fitted with a Napier Lion engine and has folded wings so that it can be stored in a small space.

One of the fastest seaplanes in the world is the Curtiss Racer, designed to defend the Schneider Cup.



Vickers Vimy Ambulance.

Inset: Opening Ceremony of Fairey Ambulance (IIID Seaplane) in British Guiana.

PLATE XIII.

It has a maximum speed of well over 250 miles an hour and is fitted with a Curtiss 500 horse-power engine. This machine is a biplane and a noticeable thing about it is the way in which every part has been streamlined in shape so as to cut down the resistance in flying to the minimum. The air screw used is made of duralumin and is unlike any other air screw used on modern aircraft. It consists merely of a sheet of metal twisted to a suitable shape, with the thinness of a knife edge at the tips. This machine, with a wheel undercarriage instead of floats, flew in 1924 at 266 miles an hour. Its minimum landing speed, 74 miles an hour, is higher than the fastest speeds of most machines before the Great War broke out, a striking commentary in itself on the rapid advance which has been made in the air in recent years.

Both flying boats and seaplanes have their own special functions and, though the advocates of the flying boat decry the float seaplane, undoubtedly the latter will continue to be used for many years to come. But the flying boat has a psychological advantage over the float seaplane. It looks what its name implies it is, a boat that flies, as a machine constantly over water should look. The flying boat is particularly suited to Great Britain and similar island countries, or countries with a long coast line. It can ride out any storm in harbour, and can be treated in every way, indeed, like a boat.

One of the largest flying boats in the world is the Fairey Atalanta, first flown in 1923. It is fitted with four Rolls-Royce Condor engines of 700 horse-power each, and was designed to operate with the Fleet, so that it could ride at anchor through severe weather and operate away from its base for considerable

periods. This large flying boat has a span of 139 feet and weighs almost fifteen tons fully loaded. It has a speed of 100 miles an hour.

The Short Cromarty flying boat, made by the famous firm of Short Brothers, the oldest firm of seaplane designers in Great Britain, was originally designed for operating with the Fast Cruiser Squadron. It has a span of 112 feet and can carry some three and a half tons, weighing fully loaded over eight tons. As a war machine it carries long-distance wireless, a big anti-submarine gun and bombs, and can ride out at sea in rough weather.

In 1923 Short Brothers produced a small all-metal single-seater flying boat in contrast to the Cromarty. The construction of all-metal flying boats will soon become as common as the construction of wooden boats and in this type of construction Shorts have taken a lead. In 1924 they produced a flying boat made of duralumin. This type of hull has the immense advantage over the wooden hull that it does not soak up water in service. A wooden flying boat may absorb several hundred pounds of water, to the detriment of its flying qualities.

In 1925 was produced and flown a large flying boat, the hull of which was made of metal throughout. This boat was built of duralumin by the English Electric Company. It is a twin engine machine and has a top speed of 120 miles an hour. This machine, like the Short all-metal flying boat, points the way to all-metal construction which will be the only form of construction for all types of heavier than aircraft in the future. Steel and duralumin construction can be made considerably lighter than wood for the same strength, and it has the advantage that it is freer from the defects of

wood, and can be made very rapidly in the case of some great emergency like war. The same firm made the P. 5 Cork flying boat, which weighs over six tons fully loaded and can fly at 115 miles an hour. These huge flying boats are far more comfortable in the air than a boat of similar size on the water. It is such boats as these which will form the nucleus of a great Aerial Marine Flying Service for the conveyance of passengers and goods along the coast or across the seas.

At the end of 1925 a flying boat weighing ten tons was built and successfully flown for the French Navy. It is driven at 100 miles an hour by four 400 horse-power Lorraine-Dietrich engines, and was designed for long distance reconnaissance work with the French Fleet. This and the Fairey Atalanta are the largest flying boats at present; but boats of thirty tons total weight are being designed, which will be capable of spending many days at sea, and will be able to fly across the Atlantic without difficulty, with passengers and goods.

The Supermarine Aviation Works are situated at Southampton, an ideal place for the construction of flying boats, for which the firm is well known. Most of their flying boats are actually amphibians so that they can alight on land or water. The Sea Lion and Scarab are both described later in this book.

The Rohrbach flying boats, which weigh nearly six tons and are driven by two Rolls-Royce Eagle engines, are remarkable for being monoplanes with very thick wings. Each machine is built throughout of duralumin and carries jury masts and sails in case of a breakdown at sea, so that it can sail home.

The United States of America have constructed

flying boats for action with the American fleet, which have a range of 2200-2500 miles. They are fitted with engines of 1500 horse-power and when fully loaded weigh eleven tons. They carry a crew of five and are constructed almost entirely of duralumin.

Amphibians are machines which can alight on land or water. Such machines are practically a necessity in countries where wide stretches of water intervene between places where air traffic is necessary. The flying boat is unable to make a direct flight over land, and the land machine cannot undertake journeys over water, without both running the risks which are avoided by the amphibian. For naval work machines of these types are invaluable, for they can get off from or alight on a seaplane carrier, or on the sea and be hoisted on board ship when necessary.

Another big advantage of the amphibian over the twin float seaplane or flying boat is that it can be brought from the water to its hanger, or *vice versá*, up and down a slipway under its own power. This is an advantage, as the seaplane or flying boat has to be placed on a trolley before being taken from or into its hangar, and the difficulties of doing this with a sea running are always great and lead to damage which shortens the life of the machine. With most amphibians the wheeled undercarriage can be drawn up into the boat.

In 1920 the Air Ministry offered a prize of £10,000 for the most efficient type of amphibian. The prize was won by the Vickers Viking Mark III. The Vickers Vickers IV, a modification of this winning machine, will carry six passengers and a pilot, and weighs, fully loaded, 6000 lbs. It is driven by a Napier Lion engine. For naval purposes the Viking carries machine guns and

bombs and has a speed of 115 miles an hour at sea-level. The Vulture amphibian is a very similar machine. Both are of the pusher type, that is, with the air screw placed behind the main planes instead of in front, as with the tractor type. The Viking is being largely used in North and South America and in Japan, as well as on the Continent and in Great Britain. It was a Vickers Vulture which was flown by Squadron-Leader MacLaren in his attempt to fly round the world.

The Parnall Puffin is an amphibian with only one float, a central one, and landing wheels. The central float is unusually long, but the machine has the advantage of being very easy to fly and to manœuvre. A remarkable point about its construction is that the tail plane is on a level with the top of the fuselage and the rudder entirely below it, so that the observer has a clear field of fire backwards. Otherwise the machine is a normal two-seater biplane fiitted with a 450 horse-power Lion engine. The Plover, made by the same firm, is a single-seater amphibian with the usual two floats and wheels which can be drawn up with the floats.

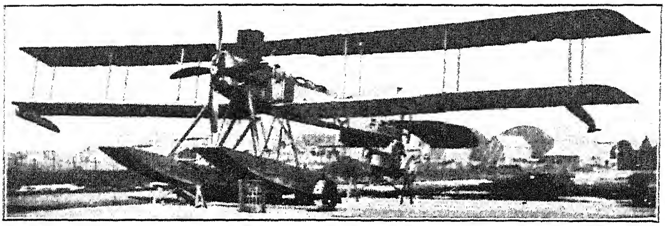
The Supermarine Sea Lion amphibian was specially built so that it would not only rise from the deck of a ship, but could operate on or from the water in rough seas. The wheeled undercarriage can be raised or lowered as required. It was a Sea Lion which won the Schneider Cup at Naples in August 1922, at an average speed of 146 miles an hour. The Sea Lion has a maximum speed over a straight course of 175 miles an hour, a very high speed for a flying boat. It weighs about a ton and a half fully loaded and is fitted with a Napier Lion engine.

The Scarab amphibian bomber was largely used by the Spanish Government for their campaign in Morocco. The machine carries, in addition to the pilot, a gunner, navigator and wireless operator and 1000 lbs. of bombs. Altogether, fully loaded, it weighs over two and a half tons and has a speed of 100 miles an hour.

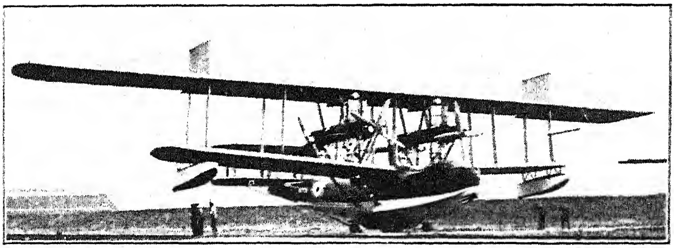
The Blackburn Aeroplane and Motor Company have specialised for some years on the making of torpedo carriers. Torpedo attacks from the air were experimented with to some extent during the Great War, and the possibilities of this form of attack were quickly realised. The navies of the future will be subject to attack from the water, below the water and above the water by torpedo and bomb, and it is difficult to see how any navy will be able to survive the attack from the air, even with a powerful aerial defence force. One of the early difficulties of torpedo carriers was the control of the aeroplane or seaplane when the torpedo was dropped. The sudden release of half to three-quarters of a ton naturally caused the machine to become temporarily very difficult to manage, at the very moment when it was flying close to the surface of the sea and loss of control was dangerous. This difficulty has now largely been overcome.

The Swift torpedo carrier is a ship aeroplane fitted with air bags to allow the machine to float in the event of a forced landing on the sea. The wheels can be dropped in mid-air so as to make landing on the water easier and safer. Like most aeroplanes and seaplanes used for naval purposes, the wings fold back. The Swift carries an 18 in. torpedo, weighs 6300 lbs. fully loaded and has a maximum speed of 106 miles per hour.

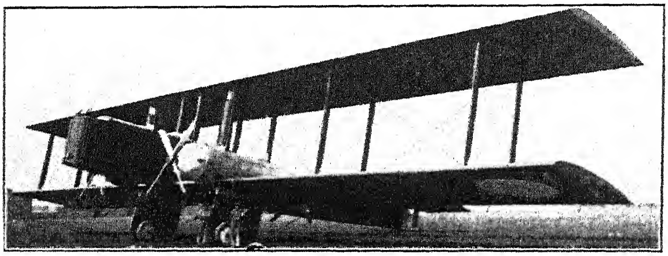
The Cubaroo, made by the same firm, is fitted with



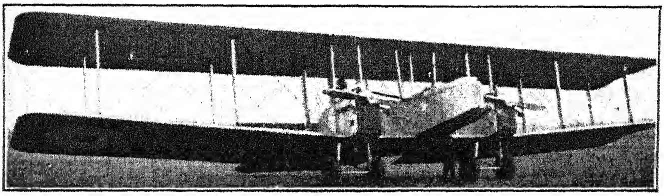
Short 225 h.p. Seaplane.



Fairey Atlanta 2,800 h.p. Flying Boat.



Farman Super-Goliath Passenger Machine.



Vickers Virginia Night Bomber.

PLATE XIV.

a 1000 horse-power Napier Cub engine. It weighs nearly ten tons fully loaded and has a maximum speed of 115 miles an hour. It has four landing wheels between which, centrally, the torpedo is carried. The Cubaroo is noteworthy for its large fuselage. The pilot and navigator can sit side by side, in front of the main planes, and they have a very wide view. The machine is also armed with machine guns and carries bombs.

The first torpedo to be carried in the air was on a Short 225 horse-power seaplane, and it was with this seaplane, the only one which took part in a naval engagement during the Great War, that a Turkish transport was torpedoed in the Sea of Marmora.

The Hanley torpedo carrier is made by Handley Page and is provided with the Handley Page slotted wing, so that it can slow up and land at a low speed on the deck of a ship. It is otherwise a standard biplane fitted with a Napier engine. When fully loaded with its torpedo, it weighs 6400 lbs.

America has specialized very largely in aircraft for work with her navy, and American warships of every type are now equipped with aeroplanes. Each battleship carries one scouting and two fighting aeroplanes, and each cruiser two scouting machines. A large number of destroyers also carry a fighting scout, and nine submarines have, so far, been provided with a scouting aeroplane which can be stowed away and taken to the bottom of the sea.

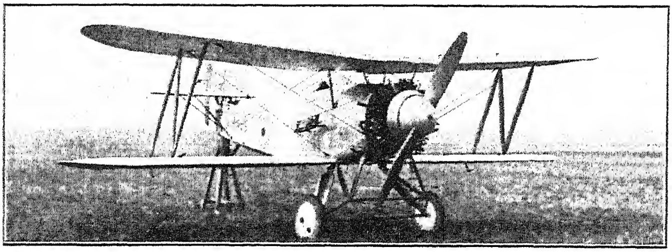
Aeroplanes are flown off American battleships and cruisers by means of powerful catapults, which render it unnecessary for the ship to steam into the wind when about to send off a machine. Two giant aircraft carriers, each capable of carrying seventy-two aero-

planes, including heavy bombers and torpedo planes, serve with the American Fleet.

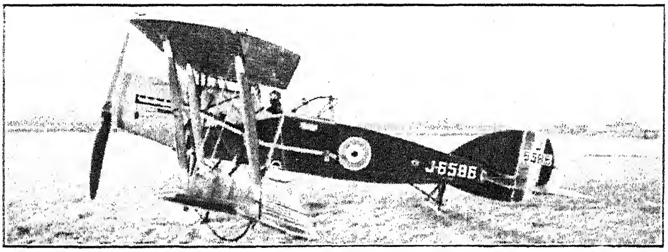
The early machines used for passenger flying after the Great War were chiefly converted fighting machines, long distance day and night bombers. These machines were not suitable for their purpose—second-hand goods of any kind seldom are—for the construction of war craft was not appropriate for passenger carrying. The interior of the fuselage of an ordinary war machine is criss-crossed with wires to keep it rigid, and these wires were a stumbling block immediately the problem had to be faced of seating passengers. In modern passenger-carrying machines, machines specially designed for the purpose, there are no wires to interfere with a passenger's comfort.

These early converted war machines were indeed comfortless in many ways. They had no proper provision for heating the cabins or for keeping them from becoming stuffy, and so many of those who after the war rushed to fly, declined to put up with the discomfort involved, and preferred to take the slower, but more luxurious, train and boat. In point of fact, the passenger-carrying aeroplane, if it is to be successful, must be as comfortable as a first-class railway carriage, and if it has to fly any long distance, it must have all the amenities of first-class railway travelling. This fact was early realized, and many of the modern aeroplanes are now exceedingly comfortable and make air travel a joy. Few people who have travelled any distance by air, nowadays, will go by any other way if they can help it.

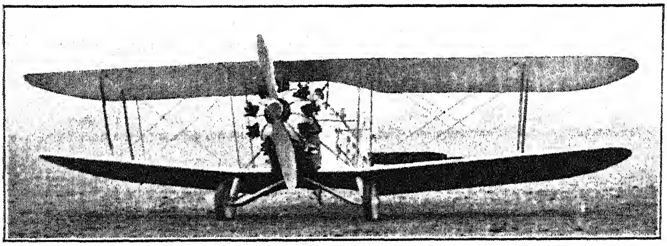
Regular aerial travel between London and Paris actually began on 26th August 1919, The Aircraft Transport & Travels Ltd. Company sending off two



Fairey Flycatcher Scout Aeroplane.



The Bristol Rolls Royce Fighter.



The Bristol Bloodhound.

The Bristol Jupiter Fighter.

machines. A week later the Handley Page Transport Company began to operate a rival line. Airco 4 and Airco 16, both developments of war machines, with a seating capacity of three to four, and Handley Page converted bombers, with a seating capacity of eight, were the machines used in those early days. They were not very comfortable compared with the modern passenger-carrying machine. Soon, however, there were developed the well-known DeH. 34 and Handley Page W. 8 types, which monopolised all British cross-Channel traffic for some years.

The DeH 34, a machine designed by Captain de Haviland, famous for the DeH machines which were so successful during the Great War, was designed as a result of several years' experience with earlier types of DeH machines on the London to Paris service. It first began to fly regularly in 1922, and carried nine passengers. The cabin is ventilated and warmed, and there is a special baggage department. Windows in the sides of the fuselage allow passengers to look out over the surrounding country.

The DeH 54 or Highclere is similar to the DeH 34 and carries fourteen passengers instead of nine. It is a large machine, and is driven by a Rolls-Royce Condor engine. The cabin, decorated in blue and grey, is wide enough for three people to sit abreast in upholstered wicker armchairs and still leave room for a gangway. The fuselage is made watertight, and the wheeled undercarriage can be dropped in mid-air in case the pilot is forced to land on the water. A fireproof bulk-head separates the cabin from the engine. Unsplinterable glass windows are fitted, so that in case of a forced landing the passengers do not have to fear being cut by flying glass. The ventilation and heating of

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the cabin can be controlled by the passengers themselves. Fresh air is taken in by a ventilator on the top of the fuselage at the front end of the cabin, while warm air is provided by means of a device on the exhaust of the engine. Hot and cold air are allowed to enter the cabin by means of a regulator which is similar to the Heat On and Heat Off regulator in a railway carriage. At the back of the cabin is a lavatory, now provided on most passenger planes, and the usual separate luggage department. The last, the aerial goods van, is necessary on an aeroplane for two reasons. One is that luggage would take up too much room in the cabin, and the other that it is best to concentrate weight as much as possible into one place, to make the control of the aeroplane easier for the pilot.

The single-engined machine for passenger flying will soon be non-existent, though cabin accommodation and the like on future machines will not alter very much. If anything goes wrong with the engine of a single-engined machine it is forced to land. With a three-engined or multiple-engined machine, however, one engine may fail and the machine will still be able to fly by using the others. Every effort, indeed, is being made to ensure that an aeroplane shall not be compelled to make a forced landing, no matter how safe the forced landing might be. For this reason all future aeroplanes on the Imperial Airways will be three-engined machines.

The Handley Page W. 8, which was used for a considerable time on the Imperial Airways route, is a twin-engined biplane. It is a twelve-seater and the cabin is provided with a luggage rack for light luggage, heavy baggage being carried as usual in a special

compartment. There are windows running all along the sides of the cabin, so that the passengers have an excellent view of the country. A Handley Page W. 8 first flew to Paris in 1919 in 1 hour 50 minutes. The W. 8 's used by Imperial Airways made many hundreds of journeys from London to Paris and back again without mishap.

In October 1925 the Handley Page HAMPSTEAD was delivered to the Imperial Airways, for use on the England-Continental passenger service. This was the first of a number of three-engined machines which will gradually replace single and twin-engined machines on most of the big air routes. The advantage of the three-engined machine is that it can fly perfectly easily if one engine fails, and can come down quite slowly if two engines out of the three fail, while, of course, it can glide down like any other aeroplane if all the engines fail, a very unlikely contingency. The three-engined machine makes it as near a certainty as possible that no such machines will be forced to land outside an aerodrome, for if even crippled by the failure of an engine they will still be able to fly.

The HAMPSTEAD is fitted with three Siddeley Jaguar engines, each developing 385 horse-power, so that the total horse-power is 1155. One engine is fitted on the nose of the fuselage, and the other two on the wings, and are all air-cooled, thus avoiding all radiator troubles and so lessening the possibilities of an engine overheating in the air. With all engines working, the HAMPSTEAD can fly at 116 miles an hour, and with two engines at 96 miles an hour. The total weight of this new type of passenger machine is six and a half tons, and it can carry fourteen passengers and half a ton of luggage. It can land at 45 miles an hour

in a calm, a comparatively low land speed, and one, of course, quite low if any wind is blowing, as the machine lands against it. So with a 20-mile an hour breeze this great six and a half ton air liner lands at only 25 miles an hour.

The Vickers Vimy, the famous bomber and the machine on which so many long-distance flights have been made, including that of the Atlantic, was converted into a very successful passenger-carrying machine. The most famous machine of this type was the City of London, which flew for some three years with consistent regularity and eventually became a freight carrier. The Vimy passenger-carrying machine had accommodation for twelve passengers. The Vickers Vanguard is a twenty-seater, and is the largest passenger-carrying aeroplane at present in regular service. The Vanguard is fitted with two Rolls-Royce Condor engines, each of 650 horse-power.

Its saloon cabin has separate armchair seats for the twenty passengers, and is electrically heated. There are a hold for luggage, lockers for mails or parcels, lavatory accommodation and a canteen for the refreshment of passengers during flights. The Vanguard can fly at 112 miles an hour and weighs over eight tons, fully loaded.

Much of the future of commercial flying in England and similar countries with a long coast line on which prosperous cities are situated, will be carried out by flying boats. Already a number have been constructed, purely for coastal and similar passenger traffic. The Supermarine Swan carries twelve passengers with luggage, a crew of two, and petrol and oil for a 300-mile cruise. It is a twin-engined machine. The whole of the hull is devoted to passenger accom-

modation. There is one large passenger saloon elaborately furnished and upholstered with every comfort, and there is more room in the boat than in most passenger-carrying aeroplanes. Forward of the saloon is the luggage compartment, fitted with racks for the storage of passengers' baggage, and aft of the saloon is the buffet, with all the necessary equipment to supply light refreshments during a journey. Still farther aft are fully-equipped lavatories. The Swan weighs 11,900 lbs., fully loaded, and can fly at over 90 miles an hour.

The most popular passenger-carrying machine in France is the Farman Goliath. It has two cabins, one aft of the wings and one, a kind of observation car, in front. The pilot and the mechanic sit between the two cabins, level with the leading edge of the wings. The Goliath is fitted with two 300 horse-power Renault engines and has a seating capacity for twelve passengers. The Super-Goliath is a four-engined machine, fitted with four 500 horse-power Farman engines, and is the most highly-powered passenger machine in the world. With one or two engines stopped, the Super-Goliath is still capable of continuing its flight. It can carry eighty passengers if necessary. It could take up in the air without difficulty a dozen Ford cars. The Super-Goliath is symptomatic of the wonderful developments in passenger-carrying machines that will be seen in the near future.

Another famous Farman machine is the Jabiru, a passenger-carrying monoplane of very curious appearance. It has a very thick, broad wing which tapers considerably towards the tips. In the centre of the wing the width is over 19 feet, while at the tips it is less than 10 feet. The Jabiru is driven by two

Hispano Suiza 180 horse-power engines and has seating accommodation for twelve passengers. Despite its unconventional appearance the Jabiru is a very efficient machine, and won a prize of 500,000 francs in 1923 for the Grand Prix des Avions de Transport under rules laid down by the Aero Club of France.

The Junkers machines were famous during the Great War. Professor Junkers has specialised in the development of thick-winged metal monoplanes. The Junkers F. 13 is one of the most successful of the Junkers passenger-carrying machines and has accommodation for six passengers. The G. 23, a three-engined machine, has accommodation for ten passengers.

The Fokker F III is another type of passenger-carrying monoplane, metal constructed throughout. It has been largely used on the Hamburg-Bremen-Amsterdam-Rotterdam service. The Fokker F. VII is a similar machine, made to carry eight to ten passengers. The Fokker machines are very easy to fly and have proved exceedingly popular on the Continent.

The use of aeroplanes as a means of conveying doctor to patient or patient to doctor is a regular occurrence in Australia on the big air routes. These machines enable a patient to be carried lying down, with accommodation for the doctor or nurse, and are specially fitted for the purpose.

In 1924 a Fairey III D was converted into an aerial ambulance for use between the up-country plantations of British Guiana and Georgetown for the transport of fever patients, doctors, medicines and other urgent supplies. The journey by air takes two hours, as compared with the usual river journey of seventeen days, and many lives have been saved by

the speed with which patients can be rushed to hospital.

Aerial ambulances are now being specially built for work with the Royal Air Force, as explained in greater detail elsewhere in this book.

Much of the success of many industries commercially depends upon the way they can be used for sport and pleasure. The motor car industry, for example, has largely been made by the interest taken in the sporting and pleasure side of it. The aeroplane industry must develop very much on the same lines as the motor car industry. The sporting and pleasure side is slowly being developed, and as greater and greater interest is shown in this side of flying by the rising generation, so ultimately will the commercial side of aviation develop.

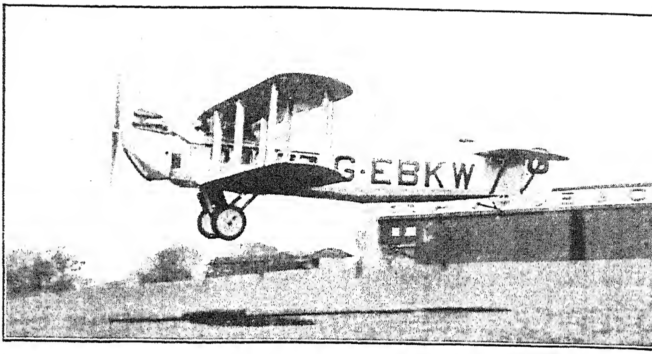
The little single-seater, the two-seater aerial run-about and the three- or four-seater for a family will come in the course of time. At the present the restrictions on flying, especially in Great Britain, are severe. It has intentionally been made difficult to obtain a pilot's licence and to be allowed to fly a machine. But these restrictions are being relaxed in the light of experience, and flying will become as much a pleasure as motoring.

The first step towards flying was by means of the glider, or motorless aeroplane. It was practice on gliders which gave the brothers Wright their success. The restrictions on flying after the Great War in Germany induced that country to develop the glider, and so great was their success, glides of three hours being made, that the subject of gliding was taken up in Great Britain and France. In September 1922 a gliding competition was held at Itford Hill in the

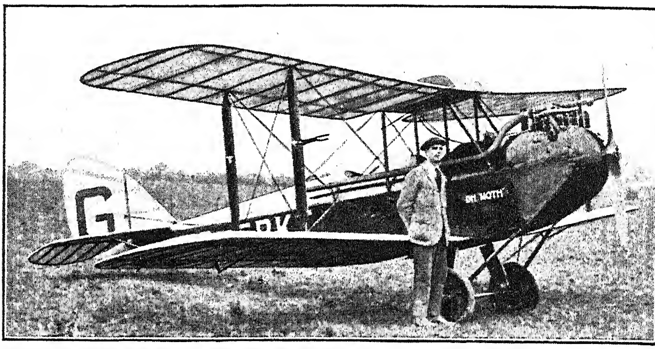
South Downs. At this meeting a Frenchman, Maneyrol, remained in the air for the remarkable time of 3 hours 21 minutes.

The results of this gliding competition led to the inauguration of a light aeroplane competition in October 1923 at Lympne, the limit of size of engines being practically the same as that for motor cycle engines. The A.B.C. 3 horse-power engine, the Blackburne engine and Douglas engine, with about 7 horse-power, were the most successful engines used. A distance of 87 miles on a single gallon of petrol was flown by the Wren and the A.N.E.C. machines, and a speed of 76 miles an hour was recorded by the Parnall Pixie, fitted with the Douglas engine. During the competition a wind was blowing, and in a calm it is certain that these figures would have been greatly exceeded, a distance of 100 miles on a gallon of petrol being easily within the capabilities of the machines and a speed of 90 miles an hour, in still air. The A.N.E.C. machine rose to a height of 14,400 feet and an Avro monoplane flew 1000 miles in the five days during which flying was possible.

The success of the Lympne meeting at once brought within the region of practical politics the provision of light, cheap aeroplanes which were safe, could fly in most weathers, were economical to run, and could be stored in an ordinary garage. The Air Ministry, realizing the importance of popularising flying, offered a subsidy of £2000 for the purchase of aircraft and a £1000 a year for maintenance for the formation of a limited number of Light Aeroplane Clubs. The clubs at present formed are the London Light Aeroplane Club, with headquarters at Stag Lane, Edgware; the Lancashire Aero Club, with an aerodrome at Wood-



Avro Andover Ambulance Aeroplane.



D.H. 60, The Moth Light Aeroplane.

D.H. 4, Puma.

PLATE XVI.

ford, Manchester; the Yorkshire Aeroplane Club, with an aerodrome at Brough; the Midland Aero Club, with aerodromes at Dunstall Park and Castle Bromwich; and the Newcastle Aero Club with an aerodrome at Gosforth, Newcastle.

The subscriptions for flying members is placed very low, £2, 2s. to £3, 3s. a year, and the machines chiefly used are DeH 60's or Moths, described later, though other machines will be used by members as they become efficient in flying. The Moths are training machines. The clubs were only formed in 1925 but already it is clear that the number of people who want to learn to fly is very large. These clubs will do more to popularise the air than anything else, and with their coming will grow up a large reserve of pilots who will be as useful in an emergency as the drivers of cars are. Some of the light aeroplanes which appeared at the Lympne meeting and are prototypes of the light aeroplanes of the future are described.

In Belgium the Poncelet light aeroplane was designed to be used either as a glider or a light aeroplane. It appeared at the Lympne meeting in 1923 and is a monoplane with a total weight of 686 lbs. It has a span of 41 feet. The engine is 17·5 horse-power, a four cylinder vertical air-cooled Sergeant.

The A.N.E.C. (Air Navigation and Engineering Company) single-seater light aeroplane is fitted with a Bristol Cherub engine, or a Blackburne motor cycle engine. Flying at the Lympne meeting it flew 87·5 miles on one gallon of petrol and climbed to 14,400 feet. It is a thick-winged monoplane, with a span of 32 feet and weighs, fully loaded, 465 lbs.

The Beardmore Wee Bee, the winner of the Air Ministry competition for two-seater light aeroplanes,

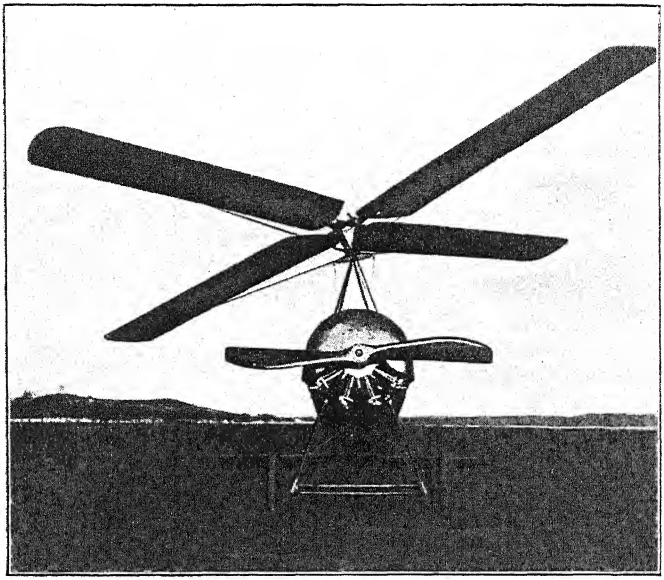
is a monoplane fitted with a Bristol Cherub engine. It has a span of 38 feet, weighs 837 lbs., fully loaded, has a speed range of 36–86 miles per hour and can climb to 21,000 feet.

The Bristol Brownie is a two-seater monoplane, with steel or wooden wings. It is fitted with a Bristol Cherub engine, and in 1924 won an Air Ministry prize for light aeroplanes. The wooden-winged machine has a span of 36 feet 7 inches and weighs 870 lbs., fully loaded, with a speed range of 36–70 miles per hour. The steel-winged machine has a span of 34 feet 7 inches.

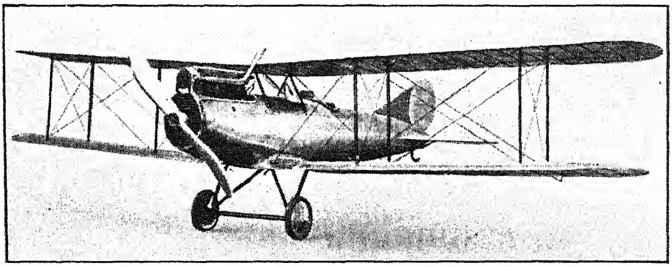
The Cranwell two-seater light aeroplane, a biplane fitted with Bristol Cherub engine, won the reliability prize at Lympne in 1924 with the remarkable performance of flying 762 miles in 17 hours 53 minutes without any change of engine or its parts. Its span is only 29 feet 8 inches ; its weight, fully loaded, 820 lbs., and its speed range 30–55 miles an hour.

The Gannet is a product of the Gloucestershire Aircraft Co. Ltd., the makers of many famous racing aeroplanes, including the Bamel, which flew at 212 miles an hour in the Aerial Derby of 1922, and won the Aerial Derby three years in succession. The Gannet is fitted with a twin Vee air-cooled Blackburne engine. It is a very light aeroplane, weighing 460 lbs., fully loaded, and having a span of 18 feet only. It is a single-seater.

The Parnall Pixie is an unusual type of flight aeroplane. A monoplane, the wings are below the level of the body. Two sets of wings are used, according to the landing speed required. For a low landing speed the wings have a span of 25 feet and for a higher one a span of 18 feet. It is fitted with an ordinary Douglas motor cycle engine, or a Black-



The Autogiro, the invention of Senhor de la Cierva.



Short Silver Streak all-metal Aeroplane.

PLATE XVII.

burne or Bristol Cherub, and has a top speed of over 100 miles an hour. Both single-seater and two-seater Pixies are built.

The DeH. 60 or Moth is the machine which was largely adopted by the light aeroplane clubs on their formation in 1925. It is built by the famous designer of all the DeH. machines which proved themselves so successful during the Great War, and later as commercial passenger carrying aircraft. The Moth is a biplane with two seats arranged tandem fashion, and fitted with dual control, so that instructor and pilot can fly together, or the owner-pilot can take up a friend with him. The wings can be folded back, so that the total width of the machine for storage purposes is only 9 feet. The Cirrus 60 horse-power engine used is fitted with a self-starter which does away with all outside assistance in starting. The petrol consumption of the Cirrus is 20 miles to the gallon. The weight of the machine, fully loaded, is 1360 lbs., and it has a top speed of 90 miles an hour, with a landing speed of 38. It was on a Moth that the Master of Sempill made his wonderful flight from London to Ireland and back early in 1926. Weather conditions were so bad that while crossing from Holyhead to Dublin he met with two such severe hailstorms that it became too dark for him to see his instruments. It is a high tribute, both to his skill as a pilot and to the air worthiness of the machine, that he was able to cross safely.

In October 1925 there was demonstrated at Farnborough a remarkable and entirely new form of flying machine, known as the Auto-giro. The invention of a Spanish engineer, Senor Juan de la Cierva, the Autogiro is the culminating effort of a long series of experiments carried out in Spain, and is the first definite

attempt to fly in a new way since the Wright brothers first flew.

The Auto-giro demonstrated at Farnborough consisted of the ordinary fuselage of an Avro machine, with a 120 horse-power Le Rhone engine driving the propeller. The tail and rudder and landing wheels are exactly as with the Avro machine. It is in the construction of the wings that a very radical change is made. In place of the usual fixed, biplane wings, an upright mast extends from the fuselage. On top are four aeroplane wings, like the sails of a windmill. These four wings, which are hinged to the central mast, are perfectly free to rotate, and are not driven in any way by the engine. The wings are long and narrow, and have a certain flexibility of movement up and down. A section of the wing is the same as that of most aerofoils.

When the ordinary propeller on the front of the fuselage begins to revolve, it draws the aeroplane along the ground, taxying in the usual way. The air, striking the horizontal windmill blades, causes them to revolve, and the faster the aeroplane moves over the ground, the faster do the windmill wings move round, until ultimately they are moving fast enough to lift the whole machine.

The Auto-giro rises into the air at a speed of a little more than 10 miles an hour. With its engine stopped in mid-air, the machine glides down in a very steep path, nearly vertical, and pulls up within a few feet. The demonstrations given at Farnborough were very largely to test the principle of Senor de la Cierva's invention, the Avro fuselage tail unit and landing chassis not necessarily being the best for the windmill wings.

These wings rotate at about 120 revolutions per

minute, and have a curious flapping motion caused by the uneven lift and resistance of the wings, one pair of which is necessarily moving forward while the other is moving backward. The Auto-giro can move in a horizontal direction at a speed of nearly 70 miles an hour, even in its present crude state. It is surprisingly easy to fly, in fact, was flown by Captain Courtney for the first time without any previous experience. There is no doubt that the Auto-giro opens up an entirely new set of possibilities in the air, and though it may not have the speed, or even the lifting power of an aeroplane, its remarkable low landing speed is one advantage which will weigh very heavily in its favour.

Not only will the future see new types of aeroplanes with new forms of wings, as in the case of the Auto-giro, but there may be new kinds of engines and new forms of construction. At the present time, for example, fresh forms of motive power are being experimented with which may revolutionize the driving of aircraft at high speeds, while metal construction has already introduced new methods of manufacture and new forms of structures. A new type of twin-engined helicopter, for instance, the Hellesen-Kahn helicopter, is now being tried. It had distinct possibilities of achieving what the helicopter sets out to achieve, rising and descending vertically in still air and hovering.

Aircraft will in the future, too, become more specialized, so that an aeroplane will be built for a definite purpose just as a motor vehicle is. There will be fast aeroplanes for sport, others purely for mail carrying, coastal cargo flying boats, long distance passenger carriers, and so on, apart from the endless variety of military and naval aircraft.

CHAPTER X

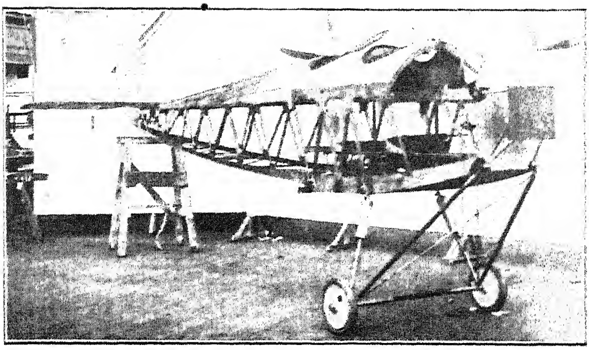
The Birth, Life and Death of an Aeroplane

Many people are concerned in the design and the making of an aeroplane before it is able to fly, before it is finally taken over by some transport company or private individual or the Royal Air Force. In this chapter a broad outline is given of the general way in which a machine is designed, and all that may happen to it before it goes out of service.

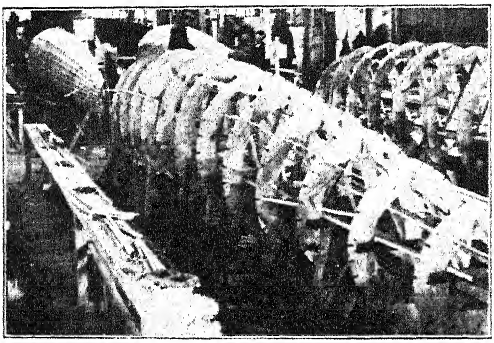
The first thing to be considered is what the aeroplane, seaplane, or flying-boat is destined to do. Is it required to carry passengers from London to the Continent, for example, and if so, how many? Is it going to be a big long-distance night-bombing aeroplane for the Royal Air Force, and, if so, how many bombs will it be required to carry, how far will it be required to fly? Or perhaps a flying boat is wanted for coastal defence, for submarine spotting work and so on. None of these things may be needed, but just sheer speed, as in the case of a seaplane or flying boat for an attempt to win the Schneider Cup.

Suppose an aeroplane firm gets some such request as the following from a big transport company—"We want a passenger-carrying aeroplane to take fourteen passengers with about half a ton of luggage. We shall want the aeroplane to be able to fly in all weathers, as far as is practicable, and it should be safe, comfortable and economical to run." These are just broad outlines, and it is the kind of thing which any passenger-carrying aeroplane company requires.

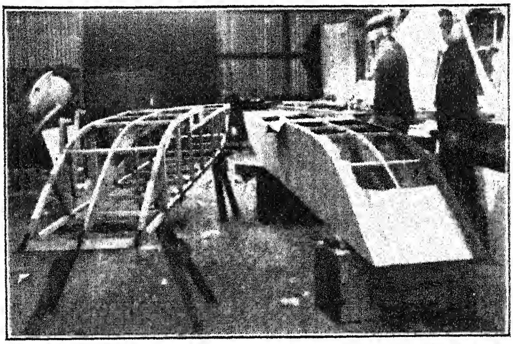
Generally every big aeroplane-constructing firm has



Fuselage construction for small machine.



Supermarine flying boat hulls under construction.



Short aeroplane floats under construction.

PLATE XVIII.

on its staff that very responsible person, the designer. When such a request comes in, he is the person entrusted with designing at least the broad basic outlines of the new machine, the kind of aeroplane which will fulfil the requirements of the customer. He is the man who designs aeroplanes, too, to certain requirements for the Royal Air Force, or he may be called upon by his own firm to bring forward some entirely new design.

Now if he is required to design a big passenger machine the first thing he has to consider is, what kind of machine must he have to lift all the passengers mentioned, fourteen in this case, and half a ton of luggage. He knows from previous experience that the total weight of an aeroplane may be divided into a number of separate parts, usually five. These five are :—

(1) The weight of the engine (or engines), radiators and propellers.

(2) The structural weight, that is, the weight of the actual planes themselves, and all their bracing wires, fittings and so on, the weight of the fuselage, rudder and tail plane, and the weight of the chassis.

(3) The weight of the petrol and oil and tanks.

(4) The necessary weights which must be carried, as pilot (or pilots) and crew, instruments, etc.

(5) The weight of the useful load, as passengers, luggage, mails ; or in the case of war machines, bombs, ammunition, etc.

Pretty well all these items are fixed except the structure weight. In the big passenger machine under consideration, for example, the weight of the useful load is the weight of the fourteen passengers and half

a ton of luggage. Suppose the average weight of passengers, to be on the safe side, is 160 lbs. each, then the total useful weight to be carried is 1½ tons. The weights of the pilot or pilots and instruments, as wireless receiving and transmitting set, are also known. The structure weight of an aeroplane, too, is known in a general way. It is found from experience of previous aeroplanes that the structure weight varies between 28 per cent. and 32 per cent. of the weight of the machine as a whole.

Other things, too, are known in a general way about an aeroplane before it is actually designed. It is known, for instance, that the number of pounds which can be lifted per horse-power lies between certain fairly narrow limits, as does the number of pounds per square foot of lifting surface. With these things in his mind the designer is able to make a preliminary rough guess at the approximate total weight of the aeroplane, with its engines and passengers and luggage and petrol and oil and any accessories, which it may be necessary to carry. This rough weight may be considerably modified later on, when the designer comes down closer to the actual design, but it serves as a basis upon which to start.

One important consideration early in his designing will be the choice of aerofoil, and this will depend upon the speed at which the aeroplane is to travel, and so on, as well as on the general purpose for which it is required. If speed alone were wanted, a high value of the lift-drag (see Chapter III) would be needed, with a low lift coefficient. But for passenger carrying, though speed is important very high speed is not. The essential thing is that the machine will be able to lift as big a load as possible, and get off the ground

as quickly as possible, with as short a run as can be managed. For that reason the wing chosen should have the highest possible lift. In some machines, as a fighting scout, it may be necessary to have high speed and lift, so that it can climb rapidly. In such a case a compromise has to be effected, and a certain amount of either speed or lift must be sacrificed.

When the probable aerofoil has been decided upon, the total lifting surface for the speed the aeroplane will just fly can be calculated. This is the lowest speed of the aeroplane, the starting speed below which the wings will not lift the weight, and the machine will come down. It is always the aim of a designer to keep the landing speed as low as possible, because the lower it is the smaller the space in which the aeroplane can land, and the safer the landing necessarily becomes. The formula for obtaining the area of the lifting surfaces is not given here, nor are any mathematical formulæ, as they are outside the scope of this book.

The area of the wings would have been calculated very roughly, when the total weight of the aeroplane is known, from the known fact that in the case of most heavy passenger machines the wings lift from 5½ to 7½ lbs. for every square foot of surface.

The aerofoil having been chosen, a rough idea of the wing surface being known, and the engines being selected, a preliminary calculation is made by the designer to see if the top speed of the machine is a reasonable one, and that it is able to climb as required. If his calculations show that the top speed is a low one, lower than is desirable for the class of passenger traffic the machine is to carry, he must start afresh with a new aerofoil.

Suppose the landing speed is 45 miles an hour, and the top speed is 100 miles an hour. Then, knowing these two facts, the designer by trial and error can find a wing section which will enable him to build an aeroplane for lifting his fourteen passengers and half-ton of luggage. Such an aeroplane would weigh about $6\frac{1}{2}$ tons in the air and require an engine or engines of about 1200 horse-power to fly. For safety's sake the designer will have two or three engines, preferably three of 400 horse-power each. The aeroplane will then be able to fly with one engine out of action, whereas, if he concentrated all the power into a single engine, the aeroplane would be bound to come down if anything went wrong.

When the aerofoil, the engines and the area of the wings have been fixed, the next step in the designing will be the actual type of machine to use, a monoplane, biplane or multiplane. Although the monoplane is most efficient in some ways, it has the disadvantage of taking up a considerable amount of room in big machines.

Undoubtedly the biplane is the best compromise in construction at the present time, for it is very little less efficient than a monoplane as regards its lifting power, and is very much more compact and easier to construct. Space for stowing away the aeroplane is always an important consideration, and it may be the designer will arrange that the wings of the machine shall fold back, as was the case with the big Handley Page bomber used during the war.

The over-all size of the machine has always to be considered, for the more compact it is the easier it is to overhaul and so on. So for that reason a biplane is better, as the width of the aeroplane will not be so

great as with a monoplane. The height may be a little greater, but height is not so important.

The length of the aeroplane will also have to be considered at this stage. Of course the fuselage can be any length, within reason, the designer likes, but, like most things to do with an aeroplane, a compromise must be effected. If the fuselage is too short, the tail is very near the wings of the machine. This means that the pilot may have to exert great strength to keep the aeroplane under control. The nearer the tail is to the wings, in fact, the more power he has to use. Not only that, but the effect of the stream of air from the propellers is much greater on the tail plane the nearer the latter is to the propellers, and this makes it more difficult to control the aeroplane in some ways.

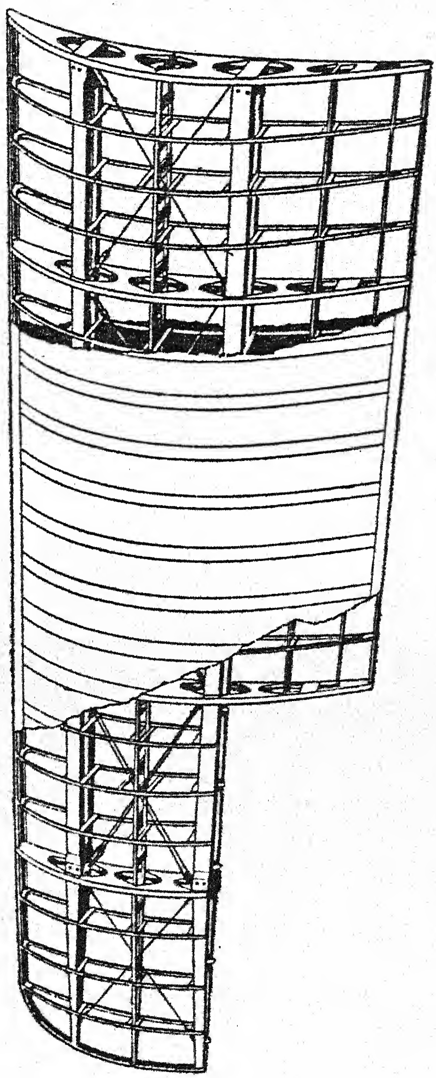
On the other hand, a long fuselage adds to the weight unnecessarily, and may make the aeroplane too easy to control, so that the lightest touch on the rudder bar or elevator control is sufficient. An aeroplane doesn't want to be too light on controls any more than it wants to be too heavy. A compromise has therefore to be effected, always with an eye on the storing of the aeroplane.

All these over-all sizes having been fixed to some extent, the designer can begin to think a little more about the details of his machine, and here a hundred and one things claim his attention for many months before the aeroplane is finally built. Everything he or his assistant designs will have to bear the stamp of compromise, for though it may be thought advisable to make wings or wires or metal fittings certain shapes so as to increase the flying capabilities of the machine, it will not always be possible to do this because of the practical difficulties of construction. Moreover,

the designer must always remember that his machine may have to be overhauled after a flight and some part of it replaced. He has, therefore, to keep an eye on the ease with which parts can be replaced or duplicated. Some machines, indeed, which are excellent machines in other ways, are so complicated in their actual construction that the replacing of any part becomes a matter of great difficulty.

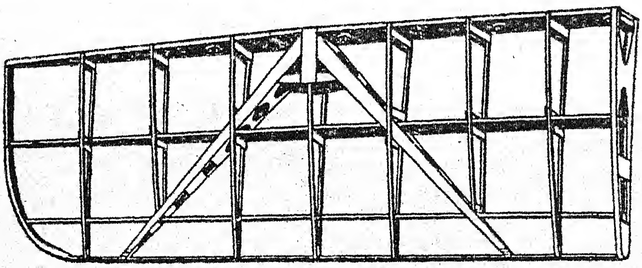
Some of the obstacles with which a designer may be faced are best seen by considering the actual construction of the many parts of an aeroplane. It may be remarked here that every single part of a machine has not only to be designed but drawn out to full size or to some definite scale by skilled draughtsmen, and checked for accuracy by the designer himself or one of his expert assistants. It is from these drawings that the skilled workmen are able to construct the various parts which are finally fitted together. Even for a small aeroplane some hundreds of drawings are required, and for a big passenger machine the number of drawings needed may be well over four figures. And every one must be absolutely accurate, as a single mistake in one drawing, if not discovered, may lead to the breaking of some vital part of the machine when in flight, with consequent disaster.

The chief parts of the wings are the main spars and the ribs. The main spars are two or more wooden or metal members which run along the whole length of the wing, from the wing tips to the fuselage. One is usually known as the front spar, and the other as the rear spar. Upon the strength of these spars, perhaps more than on anything else, depends the safety of the aeroplane, for many other parts of it are duplicated in some way or another, and these parts might be



broken without actually causing the aeroplane to break in the air. But if one of the main spars breaks, the chances of the aeroplane coming down without crashing are small.

In making the aeroplane spars, or any other parts, the two things which the designer has to consider all the time are lightness and strength. Every part of an aeroplane must be as light as possible and as strong as possible. For that reason, in making fittings, spars and so on, all superfluous parts are cut away as far as possible. The main spars, for example, are usually spindled out so that in section they appear like a capital I, or are like a hollow box in section. Main plane spars are also made of metal. This is stamped out in sheets, and riveted together to make a strong and light spar.



Joining the two spars are the ribs. These are shaped carefully to the outline of the aerofoil section which has been chosen. To them is attached the fabric which covers the wings. Actually there are many different ways of making these ribs, and their design is important, as there may be several hundred in a big machine. A few ounces extra weight saved

on each rib becomes quite an important consideration, therefore, as all this weight, if saved, can be used for carrying useful loads. At the same time the designer must be careful not to make the ribs too light or they will break.

At intervals between the main spars specially strong ribs are fixed, so as to strengthen the wing-structure as a whole. The front part of the ribs in the wing has to be made specially strong, since it is the leading edge of the wing, the edge which strikes the air first. And when an aeroplane is moving through the air at 150–200 miles an hour it will be realized that the front portion of the wing must be heavily strained always by the great pressure.

The spars and ribs are further strengthened by means of wires, known as drag wires. The ailerons are hinged to the near edge of the rear spaces at the wing tips, and are shaped to follow the general contour of the wing section. The wings, as a whole, are connected by metal fittings to the body or fuselage of the machine, or to the centre section. The centre section is that part of the wing structure situated at the body of the machine. At the nose of the wing and in between the ribs are often placed short strengthening ribs, from the leading edge or nose to the front spar.

Ribs and similar parts of a machine which have to be duplicated in great quantities and which must be absolutely accurate as regards size and shape are made on what are known as jigs. These jigs are a kind of template, or shaped apparatus which enables the workman to make up the shape of a rib very rapidly and know that every one he makes is correct. It corresponds to a rib or other part of a machine as the key does to a lock. Each part of a machine made

in quantities like this must fit its proper jig. Without such shaped jigs or guides it would be a very tedious and expensive process making sure that all the same parts were exactly the same size. And here it must be mentioned that exactly means what it says, especially with regard to metal parts. Government inspectors are employed in all aircraft works to see that all parts are the size they are stated to be, that they do not vary by more than a certain small amount known as tolerances. These tolerances in metal work are often only a thousandth of an inch, a very small amount indeed, indicating how accurate the work must be. If any part does not satisfy the Government inspector, he has the power to reject it and see that it is replaced by a part which is accurately made.

During a war, or where there is a large demand for one particular type of machine, nearly every part of an aeroplane is made by means of jigs, and the designing of these jigs themselves is a big problem. Often, too, special machines are made which can duplicate a particular part of a machine very rapidly.

In the making of metal spars and ribs and so on a large part of the work is done by unskilled labour, accurate machines being used to shape the particular parts which go to make up the metal spar and so on, and to rivet these parts together in the proper way. A machine is much more reliable than a man, no matter how skilled the latter may be, and, of course, much faster in getting the work done. But it is reliability which matters, and everything has to give way in aeroplane construction to reliability, as many aeroplane factories had up on their walls during the Great War, " Remember a single mistake may cost a brave man his life."

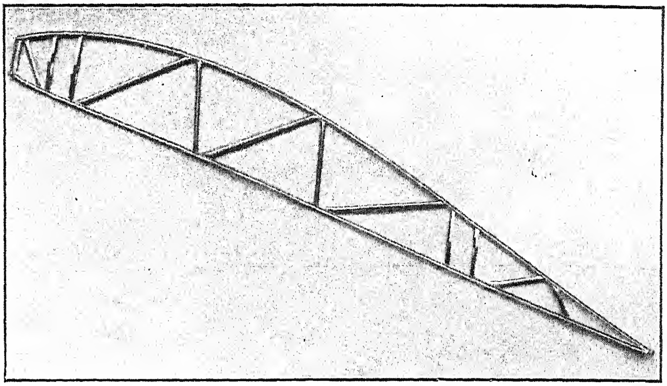
It is interesting to see how metal spars and ribs are made, for these will be the only kind of spars and ribs used on aeroplanes in a few years time, wood not only being uncertain in its strength but being too scarce to meet the ever-increasing demands upon it. There are two forms of metal construction used in the making of spars, ribs and struts. These forms consist of specially shaped metal strips and metal tubes.

Metal strips generally come into an aeroplane works in large rolls, something like gigantic clock springs. They are of various widths, and they are passed through special rolling machines. They come through these rolling machines no longer as flat strips of metal, but as corrugated strips. These corrugations differ according to the ideas of the designer, but they are all so arranged in any case that they will give the greatest possible strength for the lowest possible weight of metal. Some are just shaped like a small metal channel, that is like a U, while others have the edges of the U curled over to form lips for joining on to another strip, and others are T shaped or L shaped or shaped in various wavy forms.

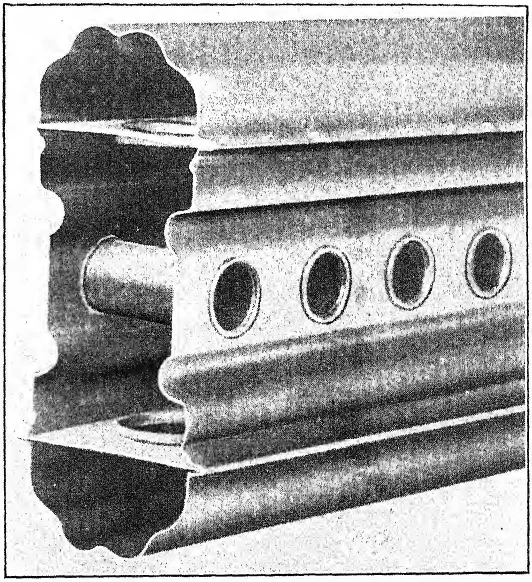
In making a metal spar, these strips are riveted together to from a kind of hollow metal box. The top and bottom of the box are called flanges and the sides of the box webs. The webs are often cut away in places by circular holes in order to make them as light as possible. At places where the chief ribs are attached the spar is specially strengthened, usually by means of a metal fitting which slips over the spar and can be riveted or bolted into position. In the course of making a spar thousands of rivets may be used, and each is accurately fixed into position by ingenious machines which drive the rivets home in

their correct holes and put heads upon them. It is very important indeed that every rivet shall be in its proper place, as the misplacing of only one rivet might seriously weaken a spar and cause a disaster.

Aluminium alloys and steel are the two chief metals used in these metal strips, and so ingenious has the construction of these strips become that it is now possible to make a wing of metal throughout that is lighter, for the same strength, than wood. And it is, of course, much more satisfactory than the wooden wing and lasts longer. It may be wondered why, in that case, metal was not always used. The answer to that is very simple. Flying has brought into use a new form of engineering in a sense, a form which demands the greatest possible strength with the least possible weight. Until flying became possible, in most forms of engineering weight was not of so much importance as strength, so careful attention was not paid to designing with a view to lightness as well. Now that lightness is as important as strength, the designing of metal work has taken on a new form, and many new ideas have been used, many new shapes, most of which were unknown until the advent of flying. These shapes were being studied during the Great War, but time did not permit them to be fully developed. Moreover there were, at the beginning, many practical difficulties in the way of shaping metal strips, in riveting them together, and so on. Wood had been used for some time, and it was, indeed, very largely due to the scarcity of good wood that aeroplane designers began to turn their attention to the construction in metal. Now, all-metal machines, like the Short Silver Streak, those made by Boulton & Paul, who have specialised in metal machines for some years, and



All-metal Aeroplane rib (Boulton & Paul).



Section of all-metal spar (Boulton & Paul).

PLATE XIX.

the metal machines of Junkers and many others, are being made. The Short Silver Streak was lighter than a wooden machine of exactly the same size and capacity, and represented such a great advance that, though built privately by Short Bros., was promptly bought by the Air Ministry. The Silver Streak was followed by the Spring Bok, also an all-metal machine.

Metal machines are becoming standardised for the Royal Air Force, and as soon as they can be replaced the wooden aeroplane will cease to be used. The Wibault, a French designed monoplane driven by a Jupiter Mark VI. air-cooled engine, is an entirely all-metal machine. The metal work is so designed that the machine can easily be made on the mass-production principle. Sheet metal is used for the covering of the wings and the fuselage instead of the usual fabric. Eighteen of these machines are, at the moment of writing, under construction for the Chilean Government by Messrs. Vickers.

Beside metal strip, metal tubes are largely used in aeroplanes. A metal tube is very strong for its weight, and is very easy to make and to fit into a machine. Metal tubes are largely used for the interplane struts of a machine, and also for the spars and ribs and for making the fuselage and parts of the tail plane and so on. They are often made streamline in shape when exposed to the air, but otherwise they are invariably circular. The wires used on a machine are streamline in shape when exposed to the wind, but circular otherwise. A streamline wire really looks more like a steel rod than anything else. It is circular at each end, so that a special fitting can be screwed on to it and the wire tightened up as much as is necessary.

Finally, the fittings of an aeroplane are all made of metal. Fittings are those metal parts used in a machine where there are joins of any kind. A wire, for example, is fastened to a fitting, which, in turn, is fastened to the main spar or some other part of the aeroplane. They are very important, for they must be carefully designed so that they shall be as light as possible and yet strong. There are many such fittings in all parts of an aeroplane, where the chief ribs are fixed to the spars, where the interplane struts are fastened to the spars, where wires are fastened in the wings and fuselage, where the main planes join on to the body of the machine and so on, and they form a very considerable part of the weight of an aeroplane. Every ounce which can be saved in their weight without lessening their required strength is so much more weight which can be carried by the aeroplane. And it is the duty of the chief designer and his assistants to design all these parts, so it will be seen that the task is not an easy one.

The wings of an aeroplane are made quite separate from the rest of the machine, and are fixed to the body or fuselage, afterwards, by special metal fittings. In many cases, especially where storage space is important, the wings of the aeroplane are made to fold, so that these fittings are also hinges, usually locked in position by bolts. When all the spars are made, the ribs, fittings, and so on, the wing is assembled, that is all these parts are put on in their correct positions. Here again great care has to be taken to ensure that each rib is in its correct position on the spars, that the fittings are properly fixed to the spars and ribs, and that the strengthening wires are the correct sizes and have been trued up, so that they are neither too tight nor

too loose. Any screws used to fasten on fittings, or bolts, have to be put in the right way. It does not do just to put a screw anywhere into a spar, or drill a hole in any odd spot where it appears to be convenient. In making the drawings of an aeroplane, every bolt hole which has to be drilled is marked, and the exact sizes and positions of such holes must be adhered to strictly. It is surprising how carefully an aeroplane must be built indeed, and what care is taken to ensure that it is built exactly to the drawings made under the direction of the designer or his assistants. Even carelessly put in screws may weaken a part of an aeroplane, and sometimes, to test how screws have been put in, an aeroplane spar or other part is X-rayed. X-rays often reveal all kinds of unsuspected weaknesses, cracks in metal which do not appear on the surface, flaws in wood, carelessly put in screws, and so on. An aeroplane inspector can not only examine the exterior finish but he can make sure that all is all right inside, a very important consideration when it is considered how carefully all work on an aeroplane must be carried out.

When the various parts of a wing have been assembled and all the interior wires properly tightened up, the next step is to cover the wing with a specially prepared fabric or metal covering. This is the covering which actually supports the aeroplane in flight, so it has to be fastened on to the ribs and spars carefully, and in such a way that it will not tear. Very strong linen is used, and it is specially protected from the effects of damp and temperature changes and the effects of constantly being out in the sun, by doping. These dopes, when painted on the linen, have the effect of tightening it up and so preserving the proper

shape of the surface of the wings. This shape must always be kept, and, of course, the large number of ribs used in the construction of the wings helps largely to keep the proper shape. Any variation would mean a variation in the lifting power of the wing, and this might have a serious effect when flying or trying to get off the ground. Where a metal covering is used, it often serves also to strengthen the wing structure itself, and it has little tendency to get slack. Metal-covered wings are coming steadily into more common use, for they have the advantage of being immune from fire, and do not suffer so seriously from the effects of temperature changes, damp, and so on. But most metal work on an aeroplane or seaplane has to be protected in some way or other to prevent corrosion. This corrosion is very serious in the case of machines which are constantly flying near or over the sea. Experiments are being carried out with stainless steel, and this material will have a very great effect on construction when it has finally been made workable. Aluminium is particularly susceptible to the effects of sea air, and must always be protected, otherwise it corrodes rapidly. Duralumin, when treated in a certain way, is hardly attacked by sea water, and is very widely used in the construction of seaplane and flying boats and ship aeroplanes.

The tail plane and rudder of an aeroplane are made in a very similar way to the main planes, on a smaller scale, and do not require any particular description. The fuselage or body of an aeroplane is constructed in various ways. One of the commonest, especially for military machines, is a long kind of box arrangement. Four long strips of wood or metal, known as longerons, form the long sides of the box, and these

sides are joined at intervals by horizontal and vertical pieces of wood, and the whole braced or kept taut by means of wires. The outside of the fuselage is covered with fabric in the same way as the wings. The fuselage usually is thickest at the point where the wings are attached. This point is known as the centre section. From the centre section to the tail the fuselage slopes, so that it is considerably smaller at the tail than at any other part.

In the front part of the fuselage is placed the engine in most single-engined machines. Specially strong members are used on which to carry the engine, known as engine bearers, or the engine may be bolted on to an engine plate attached to the fuselage. The fuselage is provided with the cockpit or cockpits for the pilot or crew; instrument board with height and speed recording instruments, instruments which indicate how an aeroplane is turning, the speed of revolution of the engine, oil pressure gauge, and so on; the control stick and rudder bar and leads to the control surfaces; and any load which may be carried, as guns, bombs and ammunition in the case of a military machine. The petrol supply is usually carried in tanks below or above the wings, in the floats in the case of a seaplane, or the hull of a flying boat or in the fuselage itself. Where-ever the petrol tank or petrol tanks are placed, however, they are in such a position that as they empty they do not appreciably effect the balance of the machine. For that reason they are placed symmetrically each side of the centre of gravity when there are two and as near as possible to it where there is only one. The petrol is fed to the engine by gravity or by a force pump according to its position. When petrol tanks are placed in the wings they are streamlined to offer as

little resistance as possible. Experiments have been tried to make the wings themselves act as petrol tanks, and it is quite possible that many machines of the future will carry all their petrol supplies in the wings themselves.

Engines are not always placed in the body of a machine. Where there are two or more engines they are usually placed in special engine nacelles between the wings, as in the case of the Blackburn Kangaroo, the big Handley Page machines, the Vickers Vimy, and so on. Sometimes only the airscrews are placed between the wings, and are chain driven from engines situated in the fuselage. No particular form of construction is standardised. Much depends upon the use to which the aeroplane is to be put. In twin-engined bombers, for example, it is convenient to have the engine units out on the wings so that the pilot and observer can sit right in the nose of the fuselage and get as good a view as possible. In many multi-engined machines of the future there will be a special engine-room in the fuselage in charge of an engineer who will have little else to do except to see that the engines are running properly and to obey any orders from the pilot in connection with them.

The construction of the body of a machine which has to carry passengers is on different lines from that of a small machine. The usual crossing wires have to be dispensed with in order to allow the passengers freedom of movement in the cabin, to allow seats to be placed in position, and to give a clear gangway down the centre of the cabin. For this reason the outside of the fuselage is strengthened and the bracing is arranged differently.

Another form of construction which does away with

the interior wires is that known as the monococque. This is a circular form of fusélage which tapers away towards the tail and is very strong and light. This type of fuselage consists of circular or oval hoops which become smaller as the tail is approached. These hoops are joined together by sheets of three ply to form the covering of the fuselage. This type of construction has another advantage in that it does away almost completely with metal fittings.

Seaplane floats are usually hollow wooden structures which are strengthened to withstand the shock of landing on the water. Flying boat hulls are either made of wood or metal. Most of them up to the present have been made of wood, and the construction follows very much the general lines of an ordinary boat. But a wooden boat has the great disadvantage of absorbing water, and in a large boat several hundred pounds of water may be absorbed. Now metal boats are being constructed and flown, the latest being a large flying boat made by the English Electric Company, which was first flown successfully towards the end of 1925. These metal boats are easier to construct than wooden ones, last longer, do not absorb water, and are more resilient.

In building an ordinary landing chassis for an aeroplane, shock absorbers are placed between the wheels and the body of the machine to take up the shock of landing, just the same as there are springs on a motor car to take up the shocks caused by the unevenness of the road. These shock absorbers usually consist of powerful rubber springs or oil shock absorbing devices. The large pneumatic tyres used also take up a considerable amount of shock, so that hardly anything is felt by those sitting in the fuselage on landing.

ing shop, to be fitted together. Here the wings are fixed to the fuselage, the tail plane fitted on, and so on.

The assembly of all the parts of an aeroplane is quite a long job, and one which has to be carried out with just as much care as has been bestowed upon the making of all the parts. The engine has not only to be installed, but all petrol, oil, and water connections made and tested. Aileron, elevator, and rudder controls are fitted and tested in position. The fitting of every part, indeed, is checked off so that when the assembly is complete it will be known for a certainty that it is complete and that some part has not inadvertently been left out.

The machine is now ready for its preliminary tests. These are usually carried out by the firm's pilot or a pilot whom they engage specially to make the preliminary tests. He makes a thorough survey of all the controls of the machine from the pilot's cockpit, learns the positions of all instruments so that he can refer to them when in the air, and then takes the machine up for its first flight in the air. It is always a tricky thing taking a new aeroplane up in the air for the first time, especially a new design which has never been flown before, and test pilots are among the most skilful in the world.

The brand new glittering machine is taken up to a safe altitude before the pilot tries any stunts on her at all. If it is a war machine he will take it up several thousand feet before he begins stunting, so that in case he finds the machine tricky he will have plenty of space in which to recover his equilibrium. This first flight is anxiously watched by the designer and his staff, for upon it may depend a greatly enhanced reputation or one which is lowered.

During these trial flights a certain number of minor defects may be discovered, but to such a pitch has modern aeroplane designing reached that it is now possible to predict exactly what a machine will do before it leaves the ground, how many miles an hour it will fly at, to what an altitude it will reach, and how fast it can climb, and so on. It is rarely, indeed, that any serious alteration has to be made.

Before the machine goes into service, military, naval or civil, supposing all is well, it has to be identified in very much the same way that a motor car has. Machines used for civil flying are marked in a different way from those used for military and naval purposes. All countries have agreed that their civil machines shall carry large letters on certain parts of their machines, the rudder, fuselage and the wings, letters which must be a certain size so that they can be clearly distinguished when the machine is flying. On the side of the fuselage of any passenger machine will be found five large letters in white on a dark background. The first of these letters is separated by a space from the remaining four, and indicates the country to which the aeroplane belongs. Thus the familiar G which appears on the Imperial Airways machines indicates at once that the machine is a British one, the letter G having been allocated by international agreement to Great Britain. All British civil aircraft not only have G as the first letter of the five painted on their fuselages, but a large G is painted on each side of the rudder. So a large F on the rudders of other aircraft indicate they belong to France, and so on. These initial letters indicating the nationality of the aircraft are followed on the fuselage by four other letters which indicate the registration number of the

aircraft in its own country. Any four letters may be used with the stipulation that one at least must be a vowel. Every machine is provided with a different set of four letters so that in this way any machine while flying in the air can at once be identified when necessary.

War machines are identified in a different way. Every machine bears a number on its fuselage and tail plane, but this is a service number which indicates to the authorities the type of machine. On the wings and the side of the fuselage is painted a device which varies with each, country and the rudder is also painted in colours which indicates the country owing the machine. Thus all British war machines have three concentric circles painted on the fuselage, the inner one being red, the middle white, and the outer blue. These circles are also painted on the planes. The rudder is painted on both sides with blue, white and red strips. France has the same colours, only the blue and red are interchanged. Germany has black Maltese crosses painted on the rudder, wings and fuselage, Holland orange circles, Belgium black, yellow and red concentric circles, America a white five-pointed star with red centre inset in blue circle and so on.

Aeroplanes are also being named as ships are. In March 1926, for example, four Handley Page machines were delivered to the Imperial Airways and christened the City of London, the City of Melbourne, the City of Ottawa and the City of Pretoria. Each firm, too, names its machines on a system. The names of most of the Vickers aeroplanes begin with a V, as the Vimy, Valencia, Victoria, and so on, as explained in another chapter.

The life of a machine after it has been accepted for

service may vary from a few hours to several years. A crash at the beginning of its career and its life is over. The City of London, one of the famous Vimy machines on the cross-Channel service, flew for five years continuously before it was finally withdrawn from service. On the whole the life of an aeroplane is short, partly due to deterioration and partly due to becoming obsolete. Types of aeroplanes are changing so fast that a machine may easily become obsolete in two years, and this particularly applies to war machines.

With the advent of the all-metal machine, however, the life of a commercial machine will be considerably longer than it is now, and overhauling and putting into repair for a fresh lease of life will be a much less tedious process.

CHAPTER XI

Aeroplane Engines

The engine is the very heart of the flying machine. But a flying machine, unlike most machines, requires a very light heart, and it was the heavy heart, the heavy engine of the past, which made flying an impossibility.

Sir Hiram Maxim was the first to make an engine for an aeroplane whose power was capable of lifting the aeroplane. The two engines he used, steam engines, weighed altogether 640 lbs. and developed 362 horse-power, a very good result indeed for steam engines at that time. But though the steam engine designed by Sir Hiram Maxim held out great future possibilities and could, indeed, have been made more powerful for less weight, the coming of the internal combustion engine soon put steam engines of all kinds into the background as far as regards high power for small weight.

In 1879 an airship was propelled by an internal combustion engine very much on the general principles and construction of the present day internal combustion engine. The engine was due to Daimler, and used benzine as a fuel. The early internal combustion engines were, however, far too heavy for use in aircraft, and it took many years of development before they approached that state of perfection which made it possible to use them.

In 1903 the Wright brothers flew with an engine which developed thirty horse-power, and weighed seven lbs. per horse-power, at 1300 revolutions per

minute. The engine was a four-cylinder and drove two propellers, by means of a chain drive, at 350 revolutions per minute. But great as this advance was it was nothing like enough, and the advent of flight and the knowledge that weight must be saved in every possible way turned the attention of designers to methods for cutting down the weight.

The first thing that was realized was that it was better to have a number of small cylinders than a few large ones, for not only could more power be obtained, but a more even delivery of power could also be obtained. Since the development of the aeroplane engine really followed that of the internal combustion engine for motor cars, the early aeroplane engines followed very much the designs of the early motor car engines, that is to say they were all of the vertical type.

The first real step forward in engine design in England was by Green, who produced a vertical engine which developed a maximum of 40 brake horse-power and weighed altogether 188 lbs. or 5·4 lbs. per horse-power, a saving of over one and a half pounds per horse-power over the engine used by the Wrights. Green followed this four-cylindered engine with a six-cylindered vertical engine of 120 brake horse-power at 1250 revolutions per minute and weighing 440 lbs. or only 3·66 lbs. per horse-power, another distinct advance. It was with one of these engines that Colonel Moore-Brabazon won a prize of £1000 for the first circular flight of a mile in England in 1909. Five years later Green won the prize of £5000 offered for the best aero engine in the Naval and Military Aeroplane Engine competition. Both the early Green engines were water cooled.

The next step forward in the design of aeroplane engines was the production of the V type. In this type the cylinders are arranged in V form over the crankshaft, so that the pistons of each pair of opposite cylinders can act from the same crank pins. The V type of engine is much more compact and considerably lighter than the vertical type of engine with one long row of cylinders. The type has also the great advantage of practically doing away with crankshaft vibration, one of the faults of high powered vertical engines.

In 1910 such an engine had been produced which weighed less than three pounds per horse-power and developed a little under a hundred horse-power. One sixteen-cylindered V type engine of 134 horse-power weighed only two lbs. per horse-power, an advance in the reduction of weight which held out great hopes for the future. The angle at which the cylinders are placed relatively to one another depends upon the number of cylinders. In an eight-cylindered V type it is 90 degrees, while in a twelve-cylindered type it is only 60 degrees.

The V type increased rapidly in popularity as its many advantages over the vertical type were realized. The Sunbeam Company produced engines designed by Louis Coatalen of high power and remarkable efficiency. The 225 horse-power engine had twelve cylinders running at 2000 revolutions per minute. It was water-cooled with cast-iron cylinders, and weighed 3·2 lbs. per horse-power. The Maori, 275 horse-power twelve-cylinder engine; the Matabele, 400 horse-power twelve-cylinder engine; and the Sikh, 800/900 horse-power engine were products of the Sunbeam Company.

The Great War pressed forward engine design very rapidly, and led to the development of the Rolls-Royce and Napier engines which are the most amazing of their kind yet produced. Early in 1915 the Rolls-Royce Company produced the first of their famous twelve-cylindered Eagle engines, an engine which was such an advance on existing types that it was immediately ordered in large quantities. This engine developed 200 horse-power, but it was improved in design, and before the end of the year was developing 255 horse-power.

Then followed an immense development. With hardly any alteration in design or the over-all dimensions of the engine it was steadily improved until by February 1919 it was developing 350 horse-power, an increase of 75 per cent. over its original horse-power. Eagle engines were fitted to most Handley Page bombers throughout the Great War, and also on the Vickers Vimy in its wonderful flight across the Atlantic. The present Eagle IX develops 360 horse-power.

Early in 1916 the Rolls-Royce Company produced a smaller engine to supply the demand for a low power engine on training machines. The original horse-power of this engine, 205, grew exactly as in the Eagle type until by the Armistice the engine was giving 285 horse-power with practically no alteration in design. The engine, now known as the Falcon III, is similar to the Eagle, and develops 250 horse-power normally.

The Napier Lion engine is an eight-cylinder V type of engine with a third row of four cylinders midway between the other two rows. This allows for a considerably shorter crankcase, and a more compact

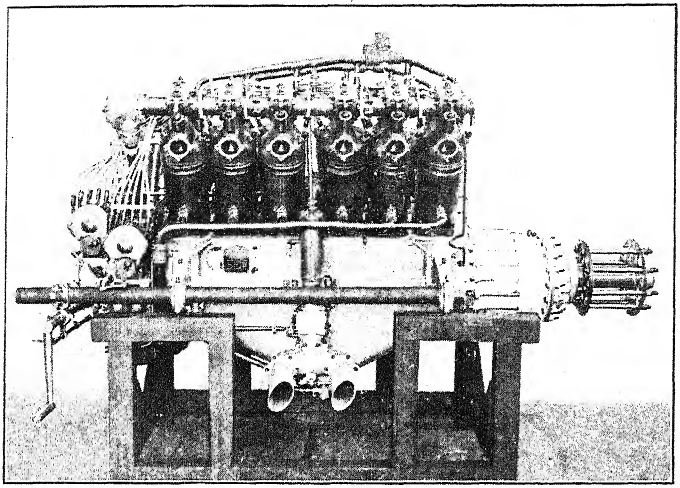
construction all round than the usual V construction. Its horse-power is 450 and weight 940 lbs.

The Napier Cub is a 1000 horse-power engine, sixteen-cylinder engine. Four rows each of four cylinders are arranged as an irregular cross round a common crankcase. The weight of this engine is only 2·45 lbs. per rated horse-power. Actually, though the engine is rated at 1000 horse-power, it develops considerably more.

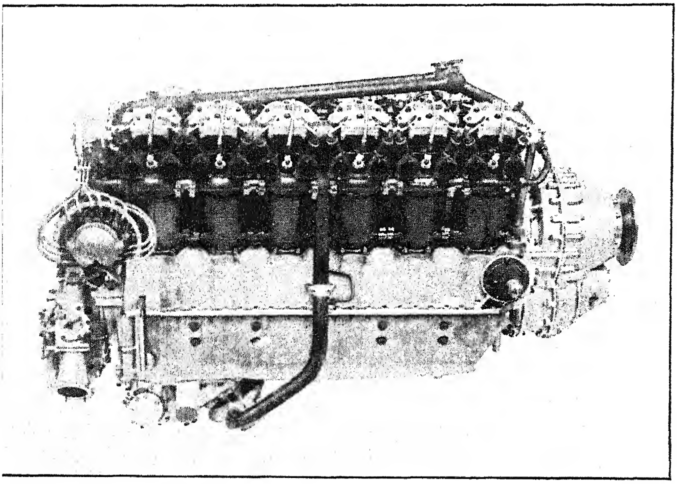
The Curtiss D. 12 engine leapt into fame as a result of its success in the Curtiss racing machines of 1921 and 1922. It is a twelve-cylinder V type and develops 400 horse-power, weighing 680 lbs. when dry. The D 12 A, a modification of the D 12, develops 500 horse-power.

In 1918 was produced the giant Condor type of engine, developing 600 horse-power, but experiments on this engine, which was a successful attempt to develop very high power in one unit, were temporarily brought to end by the Armistice.

The present Rolls-Royce Condor aero engine is of the twelve-cylinder water cooled V type, developing a normal brake horse-power of 650. A few particulars of this type of engine may be given here. At its normal power and speed (1900 revolutions per minute of the crankshaft) its petrol consumption is 45 gallons an hour, and its oil consumption 1·9 gallons per hour. The weight of the engine, including carburetters, magnetos and so on is 1154 lbs., less than 2 lbs. per horse-power. The cylinders are separately mounted on the crank case in two rows of six, inclined at an angle of 60 degrees with each other. Aluminium and duralumin enter as largely as possible into its construction.



Rolls Royce Eagle IX.



Rolls Royce Condor.

PLATE XX.

The Condor engines have been fitted to such well-known modern machines as the Short Cromarty, the Vickers Valentia, and the world's biggest flying boat, the Fairey N 4 Atlanta I. The latter machine, weighing nearly 15 tons, has four Condors.

The Lion type of engine, made by the Napier Company, was another product of the Great War. The Lion was a twelve-cylindered engine developing 450 horse-power. The cylinders were set at an angle of 60 degrees, and the normal rate of revolution was 1350 per minute. The dry weight of the engine was only 850 lbs., while with petrol and oil for six hours it weighed 2671 lbs., its petrol and oil consumption being comparatively low.

Among other V type engines of the war period may be mentioned the twelve-cylindered 500 horse-power Galloway Atlantic engine. Its total dry weight was 1535 lbs. The cylinders were arranged in two main groups of six, each group of six being subdivided into two blocks of three cylinders each with a common cylinder block of cast iron. The engine was produced towards the end of the Great War.

Another remarkable engine was the American Liberty, with twelve cylinders set at an angle of 45 degrees. It developed 425 horse-power at 1750 revolutions per minute and weighed dry only 820 lbs. The water-cooled cylinders were constructed from steel tube welded jackets. There were two valves per cylinder. This machine went into production and was largely used on Handley Page bombers and similar machines.

Mention must be made of two extensively used stationary air-cooled types of engines used during the war, the 90 horse-power R.A.F. and the 120 horse-

power Beardmore. The former was of the V type and the latter of the vertical type.

The 90 horse-power R.A.F. was an extremely efficient engine, though heavy, weighing 450 lbs. or 5 lbs. per horse-power. The Beardmore was slightly heavier, $5\frac{1}{4}$ lbs. per horse-power.

At the end of the Great War practically all the German aero engines were water-cooled. The chief engines in service were the 100 h.p. Mercedes; 120 h.p. Argus; 160 h.p. Benz; 260 h.p. Mercedes; 240 h.p. Mercedes; 240 h.p. Maybach; 300 h.p. Maybach; 200 h.p. Austro-Daimler; 270 L.O. Basse-Selve; and 200 h.p. Maybach. All these engines were six-cylindered, and the weight varied from 3·10 lbs. per horse-power in the case of the 300 h.p. Maybach to 4·85 lbs. per horse-power in the case of the 200 h.p. Maybach. With fuel and oil for the six hours these figures were 7·14 lbs. per horse-power and 9·24 lbs. per horse-power respectively.

The 160 h.p. Mercedes, a stationary engine, was fitted to such reconnaissance machines as the Albatross single-seater, the Pfalz and Fokker single-seaters; the 260 h.p. Mercedes to the F.d.H., A.E.G., and Gotha biplane bombers, and the Rumpler two-seater fighters. Benz engines were used on the L.V.G. and D.F.W. two-seater reconnaissance machines. At the end of the war 80 per cent. of the German aeroplanes were engined with Mercedes engines.

In the radial type of engine the cylinders form the radii of a circle, being fitted round a central crank-pin so that the pistons act in succession upon it. This arrangement allows a short compact engine to be made. The radial engine was practically not used by the Germans in the war.

Charles Manly, the engineer to Langley, built the first successful radial engine, a five-cylindered radial developing a little over 50 horse-power and weighing only 2·4 lbs. per horse-power. The engine was water cooled. In 1909 Bleriot flew the Channel using a French Anzani radial engine which developed 25 horse-power. These early Anzani engines were three-cylindered, one being vertical and the other two inclined at an angle of 72 degrees on each side. By 1914 Anzani radial engines of 200 horse-power with 20 cylinders were being produced. These cylinders were in four groups of five each, working on two crank pins, the total weight of the engine in running order being 3·4 lbs. per horse-power.

Another 200 horse-power radial engine in use in 1914 was the Salmson (Canton-Unne). This was a fourteen-cylindered engine. Other engines, from a seven-cylindered 90 horse-power engine to a 600 horse-power engine with eighteen cylinders were made by the same company and were largely used in the Great War. The 600 h.p. engine was in effect two engines geared together.

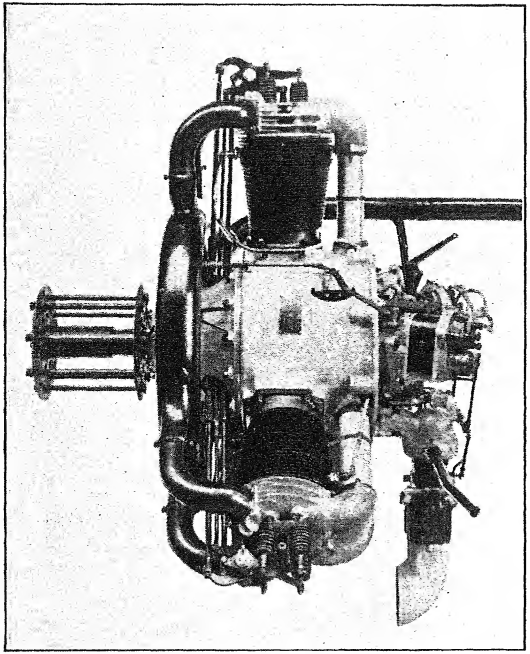
The well-known Lynx and Jaguar engines, made by the Armstrong-Siddeley Motors, are radial engines. The Lynx is a seven-cylindered engine developing 180-210 horse-power, and weighing 480 lbs. Its compactness may be realized from its over-all dimensions, 41½ ins. in length over-all, and 45 ins. in diameter. The Jaguar has fourteen cylinders and develops 385-425 horse-power. It is only five inches longer than the Lynx and has the same diameter, and weighs 770 lbs. Both are air-cooled. The Jaguar works on two cranks set at 180 degrees and the Lynx on one crank. The cylinder heads, pistons, etc., are of aluminium.

It was a Jaguar engine which was used by Cobham on his remarkable flight from London to South Africa and back. The engine gave no trouble whatever, and on being dismantled after the flight showed no appreciable signs of wear. The test which the engine had to undergo on this flight forms an amazing tribute to the efficiency of the air-cooled engine in general, and the Jaguar engine in particular.

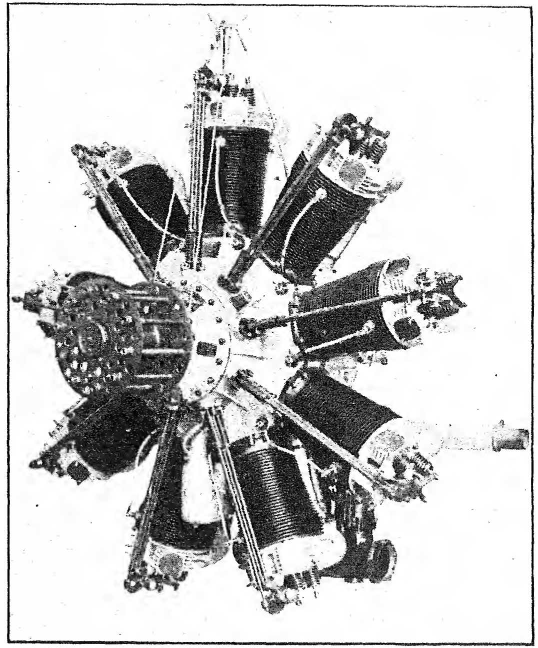
The A.B.C. Wasp 11 and A.B.C. Dragon Fly 1 A, made by Walton Motors, were seven and nine cylindered radial engines largely used in the war. The former had a maximum horse-power of 200 and weighed only 350 lbs., 1·75 lbs. per horse-power, and was very economical in petrol and oil consumption. The latter developed 340 horse-power and weighed 600 lbs., its petrol and oil consumption being at the same rate as that of the Wasp 11. They were the lightest reliable aero engines made during the war, and probably the best radial engines of their time.

The Lucifer engine, made by the Bristol Aeroplane Company, is a radial engine with three cylinders arranged as an inverted Y. Its weight is 330 lbs., and horse-power 120-140 according to speed. These engines have proved very reliable, and have been largely used on Flying School machines, and on small commercial machines.

The Jupiter engines, built by the Bristol Aeroplane Company, are examples of high-powered radial engines which are reliable and have a light weight for a high power. The Jupiter Series IV is a 400 horse-power nine-cylindered engine, weighing 780 lbs. The nine cylinders are arranged in one plane round a circular crank case, in which a single throw crankshaft is mounted on roller bearings. Three carburetters are



Bristol Lucifer Engine.



Bristol Jupiter Engine.

Plate XXI.

used operating in conjunction with a special induction system.

The Jupiter engine is largely used on military aircraft, and is fitted to the Farman Goliath, the Spad 56, the Potez flying machines, and Fokker machines among others.

In March 1926 a Jupiter Mark VI. air-cooled completed a 226 hours flying test, during which 25,074 miles were covered. It was then dismantled, and its condition reported upon by Air Ministry officials. All parts were found to be in excellent condition. The Mark VI. type develops 450 horse-power, is smaller than the previous type, and weighs 80 lbs. less.

Radial air-cooled engines have certain advantages over the vertical and V type of engines. On the whole, up to horse-powers of 1000 at any rate, the radial air-cooled engine can be made as light as any other type. The doing away with the radiator, piping and water and their attendant troubles is another great advantage. Water-cooled engines have always a disadvantage, for apart from the fact that water circulating systems are not completely reliable, corrosion is a serious problem. For naval and military purposes, too, water-cooling presents difficulties, as water may not be obtainable in some areas of fighting. In hot climates, too, air-cooled engines are better than water-cooled. It is probable, too, that in large quantities it is considerably simpler and quicker to make radial engines than the vertical and V type, and such engines are quicker to overhaul and replace.

In the rotary engine the crankshaft is stationary, while the cylinders and crankcase rotate round it. Many of the engines used during the Great War were of the rotary type.

The first rotary engine to appear was the Gnome, due to the inventive genius of M. Laurent Seguin. This type of engine has certain advantages over other types. The rotary is the lightest type of engine for a given horse-power, but it is wasteful in lubricating oil, and has a comparatively high petrol consumption. The rotary engine too, on the whole, requires more over-hauling than the stationary engine. There is the advantage, however, of more effective air-cooling. The rotary is the type of engine which is most useful where short flights are contemplated, so that the advantages of light weight of engine per horse-power will not be counter-balanced by the relatively large amount of fuel and oil which must be carried.

The first Gnome was five-cylindered, of 34 horse-power, and weighed 3·9 lbs. per horse-power. In 1913 appeared the Gnome Monosoupape, so called from the only valve on the cylinder head being the exhaust valve. Ports at the bottom of each cylinder communicated to the crank chamber into which the petrol and air mixture entered primarily. Speed variation of the engine was obtained by altering the extent and duration of the opening of the exhaust valves. The Gnome Monosoupape weighed less, and had a lower oil consumption than the early types of Gnome engine.

The 100 horse-power Monosoupape in use during the Great War had nine cylinders and weighed 300 lbs. In this type of engine there was no carburetter. Petrol was pressure fed from the tank through a main petrol tap and a fine adjustment valve into a copper pipe inside the crankshaft, and issued into the crankcase from a jet which was situated in the hollow big end of the crank-shaft. In some makes of the engine a small amount of air entered the crankcase through the leading open end

of the crankshaft and assisted in vaporizing the spray of petrol from the jet. The vaporization was further assisted by the churning action of the connecting rods and the heat of the engine. The gas was, as already explained, drawn through ports in the base of the cylinders when these ports were uncovered by the piston towards the end of the suction stroke.

The well-known 80 horse-power Gnome, largely used in the Great War, was seven-cylindered and weighed 210 lbs. The inlet valves were situated in the centre of the piston heads and the exhaust valves in the cylinder heads. The carburetter used had no float and needle valves. Petrol reached the carburetter by a pipe leading to the jet, and the amount could be regulated by a screwdown needle valve operated from the pilot's seat. The stream of petrol issuing from the jet was met by the main air supply through the carburetter at right angles and drawn with it into the crankcase, *via* the hollow crankshaft, and to the cylinder, *via* the valves in the piston heads.

The 100 horse-power Clerget was another well-known rotary engine of this period. It had nine cylinders and though normally rated at 110 horse-power developed 130 horse-power at 1200 revolutions per minute. The pistons were made of a light alloy. The inlet and exhaust valves were both in the cylinder heads. The petrol and air mixture passed through a carburetter into the hollow crankshaft.

A third type of radial, the 80 horse-power Le Rhone, extensively copied by the Germans, was, like the Clerget, a nine-cylindered engine. It weighed 240 lbs. The explosive mixture was conveyed by copper induction pipes from the crankcase to the inlet valves situated in the cylinder heads. The Le Rhone was one

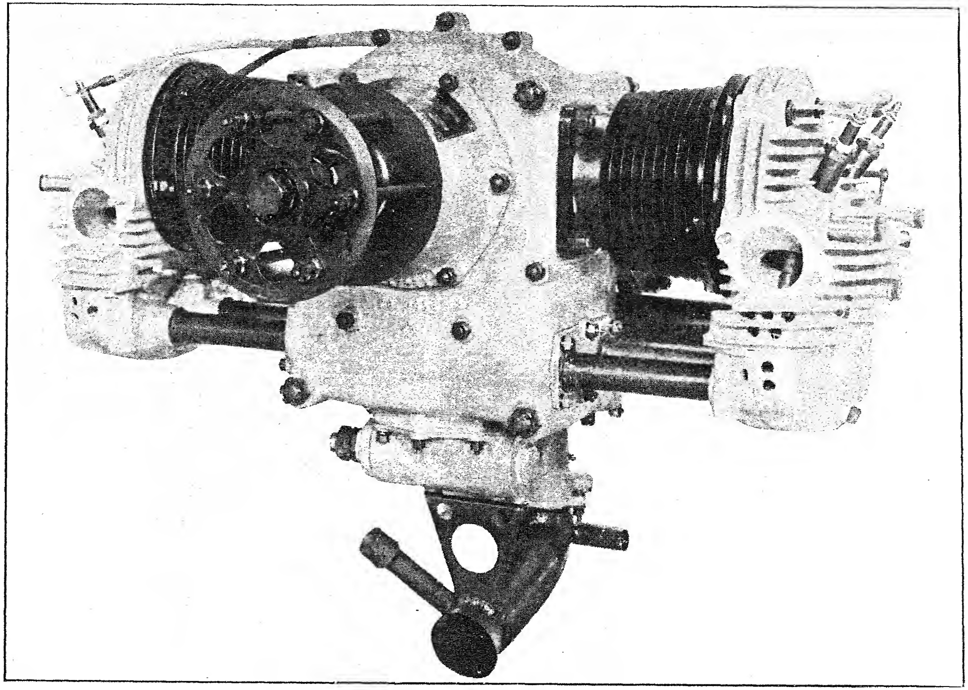
of the few rotary engines used by the Germans in the war.

The advent of light aeroplane clubs has created a demand for low powered engines, chiefly of the horizontally opposed four-stroke motor cycle type. Such engines have a perfect balance and an extremely even torque. They are eminently suitable for low powers, but are too long and bulky in the high powers.

A well-known example of the air-cooled horizontally opposed twin is the Bristol Cherub, which develops 29-34 horse-power, and weighs 95 lbs. At normal revolutions its consumption is 1¾ gallons of petrol an hour and one pint of oil. The Cherub engine is remarkable for its reliability.

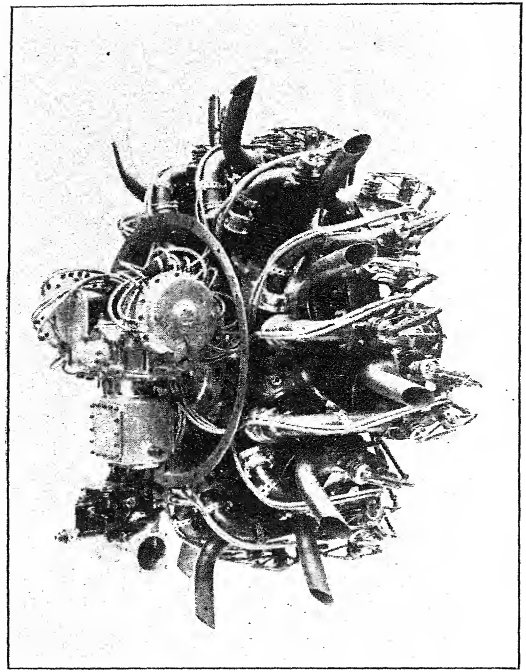
The 27/60 horse-power Airdisco Cirrus engine is a four-cylinder vertical engine which has been specially designed for low powered touring and school machines, in which robustness, cheapness and maintenance and reliability are of primary importance. It has been largely used on the De Haviland Moth for light aeroplane flying clubs. The engine is fitted with a hand-starter gear somewhat on the lines of a motor cycle kick starter. Its normal horse-power is 60 and its weight 260 lbs.

For engines of six or more cylinders it is necessary, as a general rule, to have some form of starter. One of the most effective of these starters is the Bristol gas starter, a small air-cooled single cylinder two-stroke engine fitted with a pumping cylinder. The latter draws its petrol supply from the float chamber of the carburetter supplying the two-stroke power cylinder, and pumps the mixture under pressure to the main engine cylinders. The starter maintains a gas pressure up to 140 lbs. per square inch, and weighs only 50 lbs.

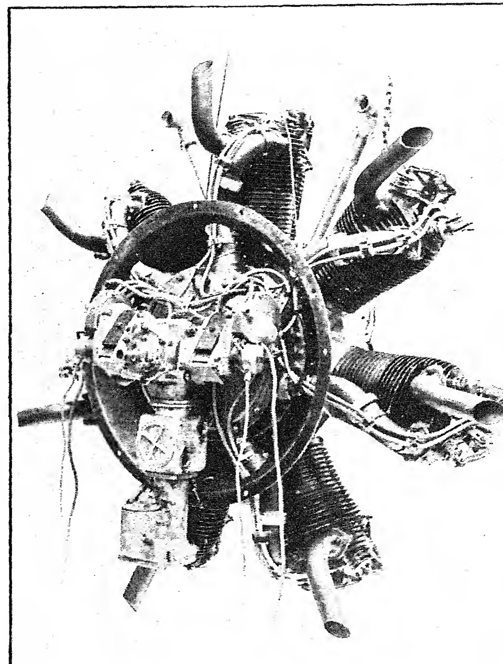


Bristol Cherub Engine

Plate XXII.



Jaguar Engine.



Lynx Engine.

PLATE XXIII.

The engine starter produced by the Aeromarine firm of America has been adopted by the American Flying Services. It consists of a small flywheel which, by means of a handle and a suitable train of gears, can be made to rotate at a very high speed. The kinetic energy in this flywheel is then applied by means of a suitable clutch to give the engine crankshaft a vigorous impulse, and so start the engine revolving.

The importance of a light engine with great power can hardly be exaggerated as far as an aeroplane is concerned. And the engine must not only be light but it must have a very low petrol and oil consumption, as a light engine with a high consumption of petrol and oil is not better than a heavy engine with a low consumption of petrol and oil.

Let us consider the kind of engine an aeroplane would want for the trip to Paris for example. Let an engine of 500 horse-power be used, and suppose it weighs 1½ lbs. per horse-power, 2½ lbs. per horse-power and 3½ lbs. per horse-power. The weights of the three engines would be 750 lbs., 1250 lbs. and 1750 lbs. respectively, or with sufficient fuel and oil for a 2½ hours' journey, 1500 lbs., 1875 lbs. and 2313 lbs.

If the first engine were used there would be a saving of weight of over 800 lbs. over the heaviest engine, equivalent to five passengers. In other words the light engine of the same power would have a greater earning capacity, could lift more passengers or goods or war material, and this is, of course, very important.

There is no doubt that in the near future powerful aero engines will be designed which weigh only 1 lb. per horse-power, and when the many light alloys now being tested have been thoroughly investigated, there

is little doubt that the time will come when an aeroplane engine will weigh only ½ lb. per horse-power.

It has been just stated that research on light alloys will largely help to bring down the weight of an aeroplane engine. Many light metal alloys are now in use, notably aluminium. Aluminium alloy crank-cases are now widely used, representing a great saving in weight. Aluminium pistons, cylinders with steel linings and so on have all been used. The Hispano Suiza engine, the B.H.P. Puma engine, the Sunbeam Arab engine, and the Sunbeam Maori engine all use water-cooled aluminium cylinders. The cylinders have steel linings to prevent the products of combustion coming in contact with the aluminium.

There is a great future, as yet not fully explored, for magnesium, which is stronger than aluminium weight for weight and very much lighter for the same bulk.

CHAPTER XII

The Aeroplane at War

No story of the aeroplane would be complete without some account of its achievements in the air during the Great War. Long years before the aeroplane was an accomplished fact novelists had visualized the war in the air, had visualized the dropping of explosives on defenceless cities from high speed aircraft against which there was no protection. The horrors of a war in the air from a novelist's point of view were very little less than the actual realities as shown by the experience of 1914-1918. And terrible as were some of the experiences of aerial warfare, there is little doubt we have hardly begun to know what war in the air really means. But it can quite confidently be asserted that when the next war does come the nation with the biggest air fleet, with the most efficient fighting machines, the nation which can replace most quickly, too, the inevitable wastage, will be the nation to win the next war. Armies and navies will in a very few years be completely at the mercy of an air fleet attacking in sufficient numbers. Even submarines have to provide themselves with aerial means of defence, and if that means of defence is overwhelmed by a superior air force nothing will prevent the ultimate destruction of the fleet.

Moreover, despite the weight of armour, armoured aeroplanes for fighting troops and all-metal aeroplanes, dropping bombs at close quarters, and armed with machine guns, are machines of the near future and, indeed, certain armoured types were in use during the

Great War. Seaplanes, too, carrying torpedoes for attacking fleets were tried during the Great War and tried successfully.

When the Great War began the Germans had no fewer than 600 aeroplanes, against a similar number by the French, while Great Britain had less than 100. Moreover most of the German machines were standardised, while those of France and Great Britain, especially the former country, were of widely different types.

At the beginning of the war there is no doubt that the German aeroplanes were greatly superior to the allied aircraft, though the superior skill of the allied pilots went a very long way to compensate for the inferiority of the machines they flew. The Germans early realized more fully the importance of air power, practised war manœuvres and provided their aeroplanes with better and more instruments than the Allies had. Most German machines were fitted with wireless, cameras, speed and height recording instruments and other instruments.

The earliest British aeroplane to go over in quantities was the B.E.2.C. The B.E.2.C. had a 90 horse-power engine. It was a two-seater biplane armed with machine guns and was very largely responsible for the British superiority in the air. The B.E.2.C. was an official machine, and later in the war it was followed by the R.E.8, fitted with an 150 horse-power R.A.F. engine. This was also a two-seater, and did an amazing amount of good work during the war. The arrival of the B.E.2.C. in France in quantities saw the end of the temporary supremacy of the German Fokker.

It is impossible in a book of this scope and size to give a detailed account of all the aeroplanes which fought the first war in the air. Much of the victory of

the Allies was due to the enterprise of private firms and their chief designers, as A. V. Roe, T. O. M. Sopwith, Short Brothers, Handley Page and others.

The first Avro machine to fly was also the first power driven aeroplane to fly in Great Britain. That was on 8th June 1908. From that time A. V. Roe constantly improved his aeroplanes, and in 1911 he produced the first seaplane to rise from British waters. Early in the Great War, Avro aeroplanes were being ordered in large quantities, and there was produced the famous Avro 504 K, one of the most famous machines in the world. It was on this type of aeroplane that more pilots have been trained than any other type of aeroplane, and more aeroplanes of this type have been built than of any other type in existence.

The Avro 504 K is a two-seater biplane with a top speed of 90 miles an hour near the ground and a landing speed of 37 miles an hour. Its weight fully loaded is 1830 lbs., and it is an extremely stable aeroplane, making it an ideal training machine. The Avro firm built many other machines, all of which played their part, but undoubtedly the Avro 504 K became the most famous, and undoubtedly deserved its reputation.

Another early flying pioneer whose machines helped to win the war was Mr T. O. M. Sopwith. It was Mr Sopwith who first built a biplane which exceeded in speed any monoplane then built, and conclusively proved that the biplane was the equal of the monoplane for the same power, a point which had been hotly disputed up to that time.

In 1915 the Sopwith Company produced their famous 1½ Strutter, the only British machine to be

adopted and standardised by the French Government for manufacture in large quantities. This machine, used for fighting, reconnaissance, photographic work, escort work and bombing, was the first aeroplane to have a fixed machine gun fitted which could fire through the propeller by means of a synchronized gear. This was an ingenious device by which the gun could only fire when none of the propeller blades was passing the muzzle of the gun. A gun on a movable mounting was also provided for the observer.

The 1½ Strutter was so called because it appeared to have only one short strut and one long strut between the two planes on each side when seen directly from the front. Early in 1916 the machine climbed to a height of 23,904 feet with a 130 horse-power engine. A similar machine in appearance, the Sopwith Pup, was designed when the Fokker monoplanes were beginning to sweep all before them on the Western Front. The Pup was a single-seater scout with a high speed.

In December 1916 there appeared the famous Camel, fitted with two machine guns firing through the propeller. It is doubtful if any aeroplane contributed so much to aerial supremacy in air fighting as the Camel. It was made in very large quantities, probably greater than any other fighting machine. The Camel, a single-seater fighter, was fitted with 130 horse-power Clerget engine. Quickly there followed the Snipe, the machine in which Colonel Barker, V.C., was attacked by sixty hostile aeroplanes. He crashed four of them and drove ten down out of control, a remarkable testimony not only to his amazing fighting qualities, but to the manœuvrability of the machine. The Snipe, a biplane, was fitted with an A.B.C. engine,

could climb 10,000 feet in $4\frac{3}{4}$ minutes, and reach a speed of 155 miles an hour.

The Dolphin which followed was fitted with no fewer than four machine guns, two firing through the propeller and two under control of the pilot. Other famous war machines of the Sopwith Company were the Buffalo, the Salamander and the Cuckoo. The Salamander was a close range, armour-piercing, bullet proof fighter, while the Cuckoo was a torpedo carrier.

The British and Colonial Aviation Company produced during the war many famous Bristol machines, as the Bristol Fighter, Scout and Monoplane. The Bristol Scout was fitted with an 80 horse-power Le Rhone engine, and was known amongst pilots as the Bristol Bullet on account of its remarkable speed of 100 miles per hour with this engine. It climbed 5000 feet in $6\frac{1}{2}$ minutes, and was particularly suited for reconnaissance work and as a single-seater fighter. The monoplane had a speed of 130 miles per hour with an engine of 110 horse-power, and would climb to 10,000 feet in 9 minutes.

The Bristol Fighter F 213, a two-seater, was specially designed for fighting and reconnaissance work. It had a speed of 125 miles an hour, and was fitted with a Rolls-Royce Falcon MK II 190 horse-power engine originally. The machine has also been fitted with the 275 horse-power Rolls-Royce engine type Falcon III, and the 200 and 300 horse-power engines. Over 1500 of these machines alone were built and flown during the war. They were also fitted with Hispano-Suiza and 240 horse-power B.H.P. Puma engines.

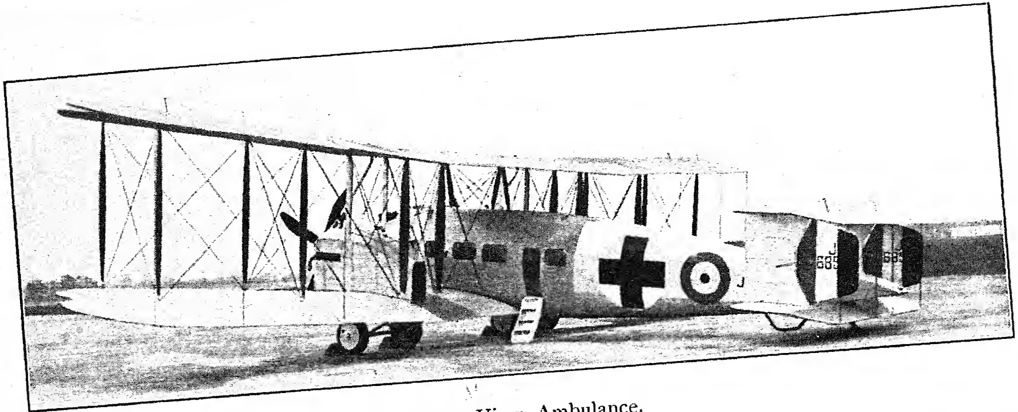
Another highly efficient series of war planes were those made by the Aircraft Manufacturing Company, Ltd., the D.H.'s., particularly the D.H. 5, a single-

seater fighter, the D.H. 4, 9 and 9 A, two-seaters, and the D.H. 6, a training machine. D.H. is a contraction of the name of the designer, Captain de Haviland, one of the best known aeroplane designers in the world.

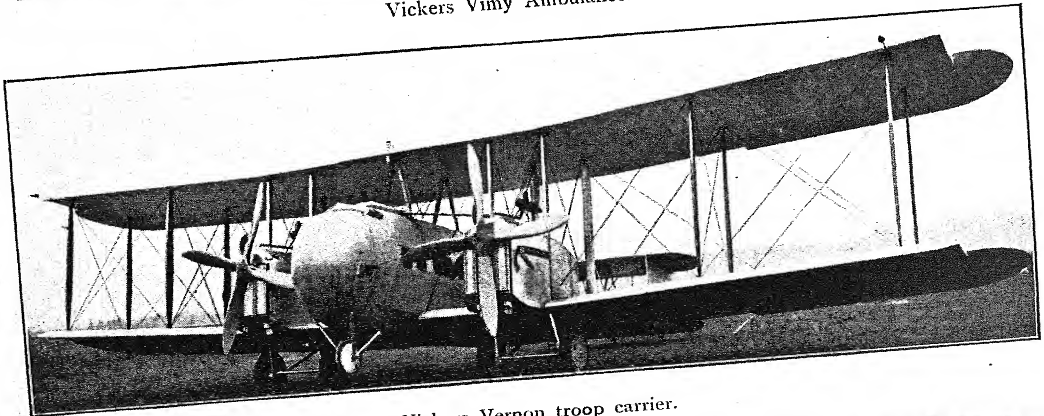
The D.H. 4 was a two-seater fighter and long distance reconnaissance machine fitted with a 250 horse-power Rolls-Royce engine. It was also fitted with a 200 horse-power B.H.P., 200 horse-power R.A.F. 3 A and other types of engines. During the war the D.H. 4's did valuable work on the fighting fronts, and for the last nine months of the war a squadron of these machines was used continuously for carrying Staff Officers and Cabinet Ministers between London and Paris and Headquarters in France. A speed of 130 miles an hour and a climb to 10,000 feet in 12 minutes were the leading performance figures of this machine.

The D.H. 9 and 9 A were similar in construction to the D.H. 4, with the exception of the front part of the fuselage. In the D.H. 9 and 9 A the pilot sat farther aft and was in a better position for fighting. These machines were extensively used for fighting, reconnaissance, etc., and by the Independent Air Force for long distance day and night bombing of the German towns. These machines had a top speed of about 115 miles an hour and a range of over 400 miles, that is to say they could drop bombs on a town 200 miles away from their base and return to the latter ready for another raid. The D.H. 6 was used in large numbers as a training machine, and was fitted with a 90 horse-power R.A.F. engine.

Vickers Ltd. early turned their attention to aeroplanes and when the war broke out they had ready for production the machine popularly known as the



Vickers Vimy Ambulance.



Vickers Vernon troop carrier.

PLATE XXIV.

Vickers Gun Bus, a pusher aeroplane, that is an aeroplane with the air screw behind the main planes instead of in front. The pilot was well in the front of the fuselage and had an uninterrupted view forward and on each side and below him. Close in front of the pilot was the observer with machine gun. The coming of the interrupter gear, which allowed a machine to fire through the propeller, did a great deal to make the Vickers Gun Bus obsolete. But though Vickers produced a number of fighting scouts undoubtedly their best known machine was the famous Vimy bomber first flown in December 1917.

The original Vickers Vimy carried over one ton of bombs, three passengers, guns and ammunition, and was fitted with two 200 horse-power Hispano-Suiza engines. She was afterwards fitted with Liberty and the Rolls-Royce Eagle engines. It was a Vimy with the latter engines which flew the Atlantic. The standard machine weighed 12,500 lbs. altogether, and had a range of 900 miles at 90 miles an hour, carrying a ton load in addition to a crew of three, so making it a very formidable bombing machine. The machine was so constructed that if one engine broke down it was able to fly on the other.

The Handley Page 0/400 heavy bomber, the product of the genius of Mr Handley Page, was undoubtedly the most successful bombing machine of the war period, and the earliest heavy bomber to be produced in large quantities. The original specification of these machines was dated as early as 28th December 1914, and the machine was called for by the Admiralty. The first machine was ready and was flown almost exactly a year later, on 17th December 1915. But at that time there had been little experience

with such big machines, and a number of troubles developed and the machine was redesigned.

The H.P. 0/400 was a long distance night bomber and had a radius of action of 350 miles. It was fitted with several types of engines, chiefly, however, Rolls-Royce Eagles. Its total flying weight was 13,000 lbs., and it carried 16 bombs, each weighing one hundredweight, and a pilot and two observers. It was armed with four Lewis machine guns, and these bombers carried out many raids over German towns. They were one of the most remarkable products of the war and the forerunner of many of the big aeroplanes of the present day. A notable feature of the machines was the ease with which their huge wings could be folded back along the fuselage, enabling the machine to be stored in a comparatively small space. Of the 122 of these great bombers completed by 11th November 1918, all except nine were fitted with Rolls-Royce engines.

For submarine spotting, coastal defence work, transport and ship escorts, the seaplane and flying boat proved invaluable. At the outbreak of the war the Short 184 seaplane, made by Short Brothers, was adopted as the standard naval seaplane, and was built in large quantities for reconnaissance and submarine patrol work. The wings of the 184 folded back so that it could be carried on board ship. The Short 320 type was the first seaplane to carry a torpedo and the first machine to demonstrate the possibilities of a torpedo carrier by sinking a Turkish transport ship in the Black Sea. Actually a Short machine flew with a torpedo in July 1914, some time before the declaration of war, and all the Short seaplanes were afterwards fitted with a chassis enabling a torpedo to be carried. Short

seaplanes did invaluable service with the Fleet during the Great War. The first Naval air raid on Cuxhaven was carried out by a flight of seven Short seaplanes; a Short seaplane was used for observation purposes during the Battle of Jutland, the first occasion in which aircraft took part in a naval engagement; and a Short machine located the German raider Konigsburg in a creek in East Africa, to give only three specific instances of the use of these machines during the Great War.

The F type flying boats were manufactured in large quantities. Twin-engined, they were used for naval reconnaissance and submarine patrol largely in the Heligoland Bight, and were capable of non-stop flights of ten hours. Many other types of flying boat, the A.D. boat of the Admiralty, the Phœnix flying boat, the Porte and so on were tried successfully during the war.

Among other British machines not already mentioned which helped to win the war in the air were the following single-seater fighting scouts, B.E. 12, the B.E. 12. Ac., the S.E. 5, and the S.E. 5a, all officially designed machines; the Martinsyde Beardmore, made by Messrs Martinsyde, Ltd., and the Martinsyde Scout, F. 3, made by the same firm; and the Vickers F.B. 19, Mark II. The following two-seaters for reconnaissance, bombing and fighting were prominent during the war, the B.E. 2E, the F.E. 2D, and R.E. 7, all officially designed machines, and the Armstrong-Whitworth F.K. 8 made by the famous engineering firm of that name. Beside the Handley Page big bomber the D/100 and O/400, the Blackburn Kangaroo, which first went through her trials as a land machine in 1917, was afterwards largely used for the destruction of enemy

submarines in the North Sea. In addition to entirely British built and British designed machines a number of foreign aeroplanes were also built in Great Britain and used by the Royal Air Force.

At the outbreak of the war German machines were more efficient than those possessed by the Allies and more standardised. The Fokker machines, founded on the French Morane aeroplanes, but considerably faster, for some months, especially in 1915, practically dominated the air. The B.E. 2c, the F.E. machines, and the D.H.'s, however, overcame the Fokker menace, and the following year came the German Albatross, the Aviatik and the Halberstadt. The Gotha, the giant twin-engined bomber which carried out a number of raids over London and other towns, was a copy of the Handley Page bomber.

Mention has been made of the Sopwith and Short Torpedo planes. Torpedo planes designed by other firms were in the course of construction during the last year of the war, and there is little doubt that this type of seaplane has an important future in aerial warfare at sea. Aerial attack at sea, indeed, has become an important part of naval strategy, and aeroplane carriers are now part of the equipment of most navies. In these aeroplane carriers machines of all types and sizes can be carried. They have special landing decks, clear of all obstructions, and can serve in time of war not only as carriers but as a floating aerodrome, where repairs can be carried out or new machines provided as necessary.

During the war many experiments were carried out to test the practicability of the landing of an aeroplane on the deck of a warship and its getting off. These tests were successful, though special methods have to

be used both for landing and getting off, on account of the short run which is possible. A landing deck is erected on many warships, and on this deck ropes are fixed which help to pull the machine up quickly on land. Machines, too, can be shot into the air by a powerful catapult arrangement.

The necessity for the use of aeroplanes as eyes of the fleet have brought into being special types of ship aeroplanes. One such type is the Parnall Panther, made by Parnall & Sons of Bristol. This machine is fitted with the usual wheeled chassis and a special pair of floats close under the bottom plane. If necessary the wheels may be released in the air, and the machine can land safely on the sea and float until picked up. The floats consist of air bags which can be inflated during flight. The fuselage is hinged so that the tail can be folded, making the aeroplane easy to transport and stow away on board ship.

The ship aeroplane has the great advantage of speed over the seaplane and flying boat, which is built to be able to moor out at anchor if necessary, and for that reason must be more strongly constructed than the aeroplane. Stronger construction means more weight and so slower speed.

At the end of the Great War, France had many highly efficient machines in service. Breguet two-seater biplanes, fitted with 300 horse-power Renault engines, were used largely for reconnaissance, photographing and artillery spotting. Similar machines were also used as day bombers, and were fitted with two or three machine guns. The bomber carried sixteen bombs.

The Caudron proved to be one of the most useful planes. It was largely used for artillery control and

bombing, having a very great lifting capacity. It was a twin-engined machine, fitted with 200 horse-power Hispano-Suiza engines.

The Nieuport biplane was one of the great successes of the war, and was notable for its very high speed and quickness of manœuvre. It was a single-seater scout, fitted with 160 horse-power monosoupape Gnome engine. The lower plane was considerably smaller than the upper, and the machine was often spoken of as the one and a half plane.

Spad machines were recognised as among the fastest for speed and climb used by the Allies during the war. They were fitted with Hispano-Suiza engines, and were single-seater fighting scouts.

No representative American aeroplane appeared on the fighting fronts during the Great War, on account of the lateness with which America came into the war. American-made De H. machines were used, however, in quantities.

At the end of the Great War the principal single-seater fighters and reconnaissance machines of the Germans were the Albatross, Pfalz and Fokker. The Albatross D III type had a speed of 109 miles an hour at 3600 feet, or 92 miles an hour at 13,000 feet, and carried two fixed machine guns. It was driven by the 160 horse-power six-cylinder water-cooled Mercedes engine, and had a ceiling of 18,000 feet. The DV type of Albatross was a slightly faster machine, fitted with the same engine, and a ceiling of 19,000 feet. The Pfalz, also fitted with a 160 horse-power Mercedes, had the then high speed of 116½ miles an hour at 6600 feet, and 103 miles an hour at 13,000. The Fokker D VII type was also a fast machine, 110 miles an hour at 10,000 feet. The Fokker triplane, which appeared late

in the war, had a high rate of climb, and was a considerably faster machine than the Albatross, and highly manœuvreable.

The F.A.H., A.E.G., and Gotha were the chief bombing planes in use in 1918, and all were fitted with two 260 horse-power Mercedes engines. The F.A.H. and Gotha were of the pusher type, that is, the propellers were placed behind the main planes. They were comparatively slow machines, their speeds being of the order of 88–90 miles an hour. They were armed with two movable machine guns and carried 7–9 bombs, their weights fully loaded being about 4 tons. The A.E.G. was a similar type of bomber with ordinary tractor air screws.

The Gotha R machine had six engines, two 160 horse-power Daimlers and four 225 horse-power Benz engines. This giant bomber did not last long, however, chiefly owing to its instability and poor climbing speed, making it easy to attack.

The Lizenz giant bomber was an improved Gotha R., fitted with four 300 horse-power Maybach engines, and driven by four propellers. Its weight was about 9 tons, and it carried over 2¼ tons of bombs. These machines were fitted also with four machine guns and four searchlights, and carried a crew of two officers and seven men all of whom were provided with parachutes,

Of the two-seater fighters which appeared in 1918, the Halberstadt and Hannoveraner were the best known. The former had a 160 horse-power Mercedes engine, and the latter a 200 horse-power (six-cylinder) engine.

The Halberstadt was one of the best two-seater fighters the Germans produced, both in regard to its

actual construction and its behaviour in the air. It had an exceptionally fine view both for the pilot and observer. Its speed, like all the later German machines, however, was considerably below that of the British fighters. Both were fast machines, about 110 miles an hour at 7000 feet, and each were fitted with one fixed and one movable machine gun. Various types of Rumpler biplanes, the L.V.G. biplane and the D.F.W. biplane, were two-seater reconnaissance machines, the first fitted with 260 Maybach engine, and the last two with 230 horse-power Benz engines. The Rumplers were considerably faster than the L.V.G.'s and D.F.W.'s. All carried bombs and two machine guns.

CHAPTER XIII

The Future of the Aeroplane

When Tennyson wrote :—

> "For I dipt into the future, far as human eye could see,
> Saw the vision of the world, and all the wonders that would be;
> Saw the heavens filled with commerce, argosies of magic sails,
> Pilots of the purple twilight, dropping down with costly bales."

he wrote more truly than he perhaps had thought.

The argosies of the skies are very near us now, and many of our sons now growing up will look upon the world in a very different way from the way our grandfathers did. In its very literal sense they will look down upon the world, look down at it from gigantic aeroplanes, from great sea-going flying boats, look down upon it from aerial runabouts, and will think of the things they see as commonplace. The aerial age of the prophet is very near, with all its unseen possibilities, with all that it might mean in the progress of mankind. And with the increase in aerial fleets little by little peace will come upon the world, for the aeroplane has no boundaries. The peoples of the world will have far vaster opportunities of getting to know one another, and that means greater understanding. And when nations, like individuals, begin to understand one another, to see each other's point of view, the chances of quarrelling, the causes of quarrelling, become less and less. As surely as, before the brothers Wright first made that epoch-making flight in 17th December 1903, the world looked upon the aeroplane as a terrible engine of war, so surely will it look back in generations to come upon the aeroplane as the dove of peace.

That is one of the inevitable things of the future, though before that era of universal peace may come there may be developments of the war machine, due to racial jealousies, due to centuries of bitter oppression, which will be terrifying in their results.

The invention of the Auto-giro, more fully described on pages 175-176, has shown that the inventiveness of man in the air has only begun. Undoubtedly the flying machine of the future will differ in many, as yet unseen, ways from its present prototype. It is difficult, indeed, to hazard a guess, but there are certain well-defined paths of progress which are now being trodden which will ultimately lead to great advances.

One of these is the present work, which is being pursued, for finding the best-shaped wing. The study of air flow is as yet in its infancy, though that infancy is a very vigorous one, and promises much for its manhood. But it is quite certain that the best shape of wing has not yet been found. The term "best-shaped wing" really includes quite a number of factors. For particular purposes at the present time there are wings which might almost be called best-shaped, that is, there are wings which enable an aeroplane to fly at a very high speed; and there are others which are known as high-lift wings. What is actually wanted in an aeroplane is a wing which has a very low resistance to forward flight and a very high lifting power at all speeds, low as well as high.

Such a wing is unlikely to be a rigid structure. It must be a flexible one, one which can give a high lift at a low speed and one which can, by suitable adjustment, be used for high speed aeroplanes. With such a wing, an aeroplane could climb fast, fly fast, and, at the same time, come down if the engine stopped,

at a comparatively small angle of glide, and land slowly. The Handley Page slotted wing, first experimented with shortly after the war, and due to the genius of Mr Handley Page, is an attempt to provide such a variable or flexible wing. It consists of a number of slots along the wing, each slot shaped like an aerofoil. They can be opened or closed to give a variable lift drag ratio while the aeroplane is in flight. Research is now being carried out on this slotted wing to find out which is the best arrangement of the slots. It may be that one or two slots along the leading edge of the wing will be found sufficient, or it may be that the whole wing will have to be slotted. Whatever the ultimate arrangement may be, this can be said, that the slotted wing, like the Auto-giro, represents a milestone on the path of progress towards the ideal aeroplane. The Auto-giro itself has a flexible wing in one sense, that is, that it varies its attitude in the air as the pressure of the air varies on it. It is semi-automatic, a more natural method of flying in some ways than the standard aeroplane.

In many ways the genius of the practical designer has outstripped the skill of the scientist in aeronautics. The Great War forced the practical man to the front, and though much research work was carried out, time could not be spared to do that work with the thoroughness which it should have had before results could be published and translated into terms which the designer could use. Many results had to be obtained quickly, even roughly, so that the designer was working sometimes with tools which were not as finely finished as they might have been. But now the scientist is once more pointing the way.

The aeroplane of the future will be as safe in the air

as the motor car or railway train is on the land, and the possibility of accidents will, indeed, be probably far less. Engines will be perfected to such an extent that the likelihood of a breakdown or a stoppage will be almost negligible. Except single and two-seaters, machines used for war and sporting purposes, practically all aeroplanes will be multi-engined, so that even in the case of something unforeseen stopping one engine, the others will enable the aeroplane to fly home safely.

Speaking of engines reminds one of the great amount of research which is going on not only towards the improvement of the internal combustion engine as a whole, but in the study of light alloys. The demand for light alloys has followed the demand of aeroplane designers for lighter engines. As a result of research carried out in the past few years, alloys of aluminium and other metals have been invented which are considerably lighter than steel and as strong. Magnesium, a lighter and stronger metal than aluminium, holds out great future possibilities.

Duralumin is one remarkably light aluminium alloy which has the strength of mild steel and weighs only a little more than one-third. It has the advantage, too, that, properly treated, it does not corrode, as do most aluminium alloys, and it is rapidly replacing wood in many aeroplane parts. According to tests which have been carried out by Messrs Vickers Ltd., the manufacturers of this alloy, the total weight of an aeroplane constructed from duralumin is only about 70 per cent. that of an aeroplane constructed from wood, for the same strength. And this metal is only one step along the road towards lightness and strength. The future will see alloys lighter still, alloys which will

withstand all conditions of weather, all changes of temperature which are likely to be met with in normal flying. Stainless steels, too, will play a part, so that the aeroplane of the future will have a much longer life than it has at the present time.

Each year sees an improvement in the engines used. They are not only more reliable, but they are developing more power for their weight. Future engines will only weigh half a pound for every horse-power developed and this alone will popularise aviation as few other things will, for it will enable an aeroplane to lift a much larger paying load. That is one of the reasons why there is a constant struggle for lightness. The lighter the actual structure of an aeroplane, the more it can carry in proportion to its total weight when fully loaded. And the more it can carry, the cheaper will flying become. It will be, indeed, very much cheaper in a few years to fly long distances than to travel by steamer and railway, for the time saved will, in itself, make for cheapness of travel by air.

New lines of attack are being developed in many directions, which may lead to some entirely new form of motive power. The internal combustion engine is by no means the last word in engines, any more than petrol is the best fuel to use. New forces have been discovered in the last decade which have not yet been usefully harnessed, and new fuels are known which have not yet been produced commercially. But the demand of aerial transport is turning the attention of the scientist and the designer towards these new sources of power, and another decade may see some new form of motive power applied to aeroplanes which will increase their flying speeds and their range.

The flying machines of the future will be as special-

ized as are other methods of locomotion of to-day. There will be great air mail liners which will fly as regularly from point to point as the mail trains travel now, more regularly, indeed, for they will not be held up by weather. The worst storms, the densest of fogs, the blackest of nights will have no effect on these liners of the air. They will be able to ride triumphantly over the storm, to rise to great heights when necessary. In their well-lighted, warmed cabins aerial sorters of the flying post office will work all through the night making ready the mail bags of each town they reach. The flying post office will serve towns many miles apart, will glide gracefully down over the local aerodrome, and drop its appropriate mail bags by parachute, and then rise, without landing, for its next aerial port of call. The flying post office will be international, for His Majesty's mails will be delivered direct from London to Paris, Amsterdam, Stockholm, Berlin and a hundred and one other important towns in Europe.

Daily, great flying amphibians, machines equally at home whether they alight on the land or the water, will make the journey from London to New York in a matter of fifteen hours or less. These great night planes will carry huge searchlights to sweep the far horizons and herald their coming, and wireless which will enable them to keep up a continuous telephonic communication with both London and New York. They will, once they have fairly started on their long journeys, practically fly themselves, for the pilot will have but little to do. They will be automatically stable, so that they will right themselves in gusty weather, and will keep automatically the correct height as determined by the pilot.

In the wake of the flying post offices will follow the long distance passenger planes. There will be different flying levels apportioned for these machines, which are constantly passing to and fro over the great aerial traffic routes, so that the chances of collision will be reduced to a minimum. Each aeroplane will carry its port and starboard lights as it does now, so that the danger of collision will be small. The cabins of the great passenger planes will be warm, comfortable, well lighted. There will be a dining-room for passengers where they can obtain a meal as well cooked as they would in a restaurant; a saloon where they can sit in comfort and amuse themselves, or be amused, where the latest news over the wireless will be displayed and the latest music played to them, and sleeping berths where they can pass the hours of the night and wake up a thousand miles farther on their journey. They will go to sleep maybe with a snowstorm raging below them, and wake up in the glorious sun of a cloudless sky.

At intervals the long distance aerial liners will overtake smaller planes hurrying along in the sky to intermediate aerial ports, there to leave their passengers, or perhaps hurrying to some great central aerodrome which serves the aerial as a port of call.

Plodding heavily on their way at 100 miles an hour or so, the travellers in these fast passenger planes will see at intervals the aerial cargo carriers, heavily-laden aeroplanes, bearing their freights to distant cities, food and the necessaries of life, and the luxuries of a modern civilization. As the passenger plane crosses a coast line, its occupants may see a coastal flying boat following the shore, serving the coast towns. One may suddenly turn inward as it bears its cargo of fish

towards the inland capital of its country, landing on an inland waterway. Maybe, too, there will appear like some angry wasp in the sky, a fast-flying two-seater racing across the sky in chase of some aerial smuggler, some aerial breaker of the international air laws. High overhead the aerial police will fly, watchful, ever ready to close up to some aerial stranger and demand his credentials over the wireless telephone. And if those credentials are not satisfactory, there will come a sharp order which will be enforced if necessary by the threat of the machine gun the aerial police craft will carry. And the stranger will be compelled to glide down to the nearest aerodrome, there to have his papers overhauled, his craft searched.

Every aeroplane will carry its proper papers, papers which will be as important as those of a modern steamship. One of the most important of these papers will be the Airworthiness Certificate, without which no aeroplane will be allowed to fly. Such certificates are, of course, issued at the present time, and they certify that the aeroplane is strong enough and correctly designed, and so on, for the weight it is carrying. There will be clearance papers, papers which signify that the authorities at the last port of call, or the home port, have recently examined the machine and are satisfied it is fit to fly. There will be papers indicating the goods and passengers being carried. The pilot, too, will have to carry his flying certificate, a certificate which must be renewed every six months. Every care will, indeed, be taken by the authorities to see that the liners of the air are safe and have a right to be in the air.

So much for the three great services of the air, the mails, passengers and goods. In addition, there will

be many machines flying on special duties. Here some of these are considered.

Throughout the world there are vast stretches of land which have never been surveyed by man, hardly even trodden by him. In South America, India, Burma, Canada, Australia, and Asia and Africa are deserts, prairies, impenetrable forests, swamps, mountain ranges, and so on, which have yet to be explored, have yet to yield up their secrets. And the possibilities of those secrets being revealed from the air have already been realized.

In many parts of the world aerial surveys are taking place. As recently as 1924 and 1925 the great Irrawaddy Delta in Burma was surveyed by Major C. K. Cockran-Patrick. Such survey work was carried out by a seaplane, actually the well-known D.H. 9, fitted with floats. The seaplane flew up and down photographing the impenetrable forest and swamp below it. Over 15,000 square miles were photographed to provide the necessary photographs from which the survey maps could be made. To make these survey maps in the ordinary way would take twenty years. By aeroplane the survey was carried out in three months.

The remarkable speed by which aerial surveys can be carried out, their accuracy, and their independence of ground conditions, have focused the attention of all ordnance survey authorities on the advantage of the aeroplane. In a few years there is little doubt that the whole world will be re-mapped from the air, and not only will many of the blank areas on present day maps be filled in, but many errors will be corrected. An experimental survey has already been carried out in England with a view to re-mapping Great Britain

in this way. Surveying from the air enables one, too, to visualize a country in a way which is not possible by any other method.

In the aerial surveys of great districts like the Irrawaddy Delta, the basin of the Amazon and so on, several areas of valuable trees were discovered which would otherwise be unsuspected. The photographs taken from the air in the Burma surveys were so clear that the trees could actually be counted and the value of the growing timber closely estimated.

Two more examples will suffice to show the possibilities of aerial survey. In July and August 1924 an aerial photographic survey of Northern Canada, covering an area of 15,000 square miles, was successfully carried out by the Royal Canadian Air Force. The total flying time for this survey was only 44 hours 10 minutes, some 1700 photographs being taken. A Vickers Viking Amphibian was employed, and during the greater part of the flight the machine was operating away from all communication. For this reason, beside a crew of four and photographic apparatus, it was necessary to carry an engine and other spares, and emergency rations for the crew. During the flight many errors in the existing maps were discovered, and a survey was carried out in two months which would have taken ten times as many years by the ordinary methods of survey.

In May 1922, Colonel Williams left Toronto, in Canada, and flew to North Bay, thence over the district between Sudbury, James Bay, and Fort William, returning to Sudbury in July, after having travelled some 13,000 miles, mainly in connection with mapping the unexplored regions of Ontario, and doing forest fire patrol. The whole of this survey was done

on a Vickers Viking machine, with no mishap of any kind.

There are many other instances of the mapping of great aerial routes, unexplored tracts, and so on, which could be given if space permitted. In the next decade or so, the world will have been mapped and photographed from the air, and it will truly be said that there will be no more regions left for man to explore. The immense unlocked tracts of Africa, Asia, North and South America and Australasia will no longer have to wait untold years for the coming of the railway to open them up. The aeroplane will do for them in a few years what might take the railway ten times as long. The aeroplanes, indeed, will act as a great coloniser, and many communities of the future, in the hearts of the great continents, will keep in regular touch with the world by air.

Coming from the more purely commercial side of the future, there are two other developments in the air which must be touched upon, the sporting and the military.

The year 1925 saw the inauguration in Great Britain of flying clubs for light aeroplanes. This is the first step in the popularization of the air, and the light aeroplane, the single-seater aerial runabout, will be to aviation what the motor cycle is in motoring. It will engender in the rising generation that enthusiasm for the air which will change the outlook of many hundreds of thousands of those who are not yet in their teens.

The light aeroplane will be a small-powered machine which can land in a small space, can be handled by one man on the ground, and can be kept in a small shed. Its wings will fold back, and the whole machine will be as easy to manage as the modern motor

cycle. In its train there will come the two-, three- and four-seater, the cheap motor cars of the sky, and a family of the future will think as little of taking an aerial holiday over Europe as it does now of taking a motor-car tour through England. But the pilot of these little aerial runabouts will have to pass far more severe tests than do the drivers of motor cars, and he will have to be certified fit to fly at regular intervals of six months. The sky will, indeed, be made safer than the road.

With the coming of the light aeroplane there will inevitably spring up aerodromes or landing fields, not only in Great Britain but in all parts of the world. There the aerial motorist will be able to get his petrol supplies replenished, learn the latest weather reports, and at the central aerodromes find all the amenities which the motorist of the road expects, hotels, garage accommodation, repair depots and the like.

The light aeroplane will be automatically stable and fitted with instruments which will warn the pilot if his machine is taking up a dangerous attitude which may lead to disaster. There will be many types of these light aeroplanes, as many types, indeed, as there are motor cars. The man in the street—and indeed, some aeroplane designers—is still obsessed with the idea that in its main general outlines the flying machine of the future is fixed, that it will have one or more planes, a fuselage, a tail plane, an engine and a landing gear of some kind, as at present. It is more than probable that the aeroplane of the future will differ widely from that of the present day, and that the light aeroplane will show the way towards new types. The Auto-giro, Captain Hill's tailless aeroplane, and so on, are only signposts on the way.

The demand for big aerodromes to be as near big cities as possible will lead, ultimately, to the construction of such aerodromes in the cities themselves, especially when new types of machines which the future will bring forth enable landing and rising from small areas to be possible. Landing stations will undoubtedly be built in big cities, probably over the railway termini of the main railways, thereby facilitating the final stages of transport. At present it is not a commercial proposition to fly comparatively short distances, say 100 miles or so, in thickly-populated areas in Great Britain, chiefly on account of the time lost reaching the aerodromes on the outskirts of the towns. With landing stages in the centres of cities, within easy reach of railway termini, one of the drawbacks of the aeroplane for this type of transport will be swept away, and the speed gained will result in a greater demand being made upon aerial transport, for the aeroplane will always be able to beat any other form of transport where speed is necessary. It is in the crowded areas that the aeroplane will come into its own, as much as it will flying between crowded areas across great trackless wastes.

As an engine of war the aeroplane will, ultimately, dominate all other methods of warfare. Its possibilities were barely seen during the Great War. It has been said that finally the result of a war depends upon the ultimate fighting unit, the infantryman. That will probably always remain true, but this is also true that the winning of a war depends very largely upon the mobility of the infantryman, and the nation which turns its attention to this factor above all others will be the nation in the best position for victory.

That problem of the mobility of the infantryman will be solved by the aeroplane. The future will see huge troop transports of the air moving bodies of men from place to place at high speed. A regiment will fly to its fighting position, accompanied by aerial fighting cruisers to ward off attack, aerial scouts to give warning of attack, and Aerial Army Service Corps with supplies. Accompanying them will be the Aerial Ambulance. Already these things are foreshadowed. The Vimy Ambulance, built by Messrs Vickers, has a specially fitted up cabin for stretcher and other patients, and is fitted out with emergency medical stores and appliances, including an ice chest, fresh water supply tank and the like. In April 1923, 198 cases of illness among the troops operating in Northern Kurdistan were transported to Bagdad by air, and a further 161 patients were transported in the same way to the Royal Air Force hospital in May, June and July of the same year. In one case, where an aerial ambulance was forced to descend, a two-seater aeroplane was sent to the spot with a medical officer as passenger, who remained with the sick and successfully treated them.

The Vickers Vernon and Victorian are specially designed troop carriers, more fully described elsewhere, and are significant of the trend of aerial warfare. As troops will be carried, so will guns, ammunition, stores of all kinds, and so on, to the fighting lines. There will be mobile cavalry of the air, whose functions will be very much those of ordinary cavalry. There will be air battles on a scale hardly dreamt of, when the toll of machines in a single battle will run into thousands. In the forefront will be the wasps of the air, small single-seater swift fighters, and behind them the

great battle planes, defending the aerial line. Once that line is penetrated, the fate of the country behind will be a terrible one if the war is carried out to its pitiless conclusion.

In the rear of the battle planes will be waiting the giant bombers, ready to raid the wealthy cities and the manufacturing centres of the enemy. From each will rain bombs of half a ton or more, bombs filled with high explosives which will cause widespread devastation and instil in the civilian population an insistent demand for peace. The threat alone of such destruction will, in many cases, lead to the suing for peace. It was only towards the end of the Great War that the possibilities of bombing on a large scale were realized, that efforts were made to construct the special kinds of bombs to give the most effective results. And the bombs of the future will not only be high explosive destruction bombs, but bombs containing poison gases under pressure, gases which will disseminate death over wide areas.

The final means of defence against such an aerial bombardment must always be by aeroplane, for it is unlikely that anti-aircraft gunnery will be able to put up such a barrage of fire that no aeroplane will be able to get through it or above it. For that reason every town of importance will be defended by a great aerial ring. At all strategic points of approach there will be aerodromes equipped with fast-flying fighters, ready to ascend into the skies to defend the city from attack. Such aerodromes will be situated several miles away from the town they are defending.

Big fighting aeroplanes will not only be armed with machine guns but guns firing shells, and new forms

of range finders will come into existence for dealing with this new form of warfare.

An added terror will appear in the future in the aeroplane with silent engines. As long as the propeller is in action all noise will not be eliminated, but aeroplanes will be much less noisy than they are at present, so that it will be difficult to detect their presence until perhaps the first terrifying rain of high explosive bombs and poison gas shells descends upon the sleeping city. Not only will the great night bomber of the future be almost silent, it will be practically invisible. New methods of comouflage are being experimented with, leading to astonishing results. In March 1926, for example, the first of a new type of bomber was delivered to the Royal Air Force. The wings, fuselage, and the rest of the machine are painted with a special green-tinted dope which renders the machine practically invisible at night.

Many aeroplanes of the future will, undoubtedly, be fitted with apparatus so that they can replenish their petrol supplies in the air from flying tankers. Experiments on these lines have already been carried out, and this replenishing of fuel will add greatly to the range and endurance of flight of the great bombers.

It will be more difficult to destroy the fighting machines of the future by machine gun fire, for they will be constructed entirely of metal, even the covering of the wings. The pilots will be protected by armoured plate. Machines will be specially constructed with armour-plated bodies, so that they can descend and fly close to the ground and open up a stream of machine-gun fire on enemy troops. These machines will fly at speeds of 200 miles an hour or more, making them extremely difficult to hit in any case. And their

construction will be such that many parts may be shot away without putting the aeroplane out of action.

At sea there will be flying boats for coastal defence, for submarine spotting, for attacking ships of war. Seaplanes will carry torpedoes, and the battle fleet of the future will be faced by attack on the sea, under the sea, and above the sea by bomb and torpedo and gun fire. It is an arguable point, indeed, whether the surface fighting craft of the future will exist. A hundred torpedo carriers can concentrate on one battleship, and it is difficult to see how at least one cannot fail to find its mark. There will only be a reasonable chance of safety under the water or in the air, and the Great War showed that the safety of under-water craft is steadily diminishing owing to aerial spotting.

If there is a navy in existence then, its chief method of defence will be an aerial one. Every big battleship will carry its quota of fighting aeroplanes, will have its landing deck. And every fleet, and units of fleets, will be accompanied by special aeroplane carriers, ships which can stow away reserve aeroplanes and repair them. Special types of aeroplanes will be evolved, a development of the present-day amphibians, which will be equally at home landing on the deck of a ship or on the surface of the sea.

These are but a few possibilities of the future. The far-reaching effects of the coming of the aeroplane on life in war and peace have yet to be visualized in their entirety. To-morrow a new type of engine may be evolved, a new form of wing invented, a new kind of flying machine brought into existence, which will largely nullify any predictions of the future based upon experiences of the past.

We are living in the greatest age man has yet seen, an age of vast possibilities, of kalcidoscopic changes in which a single decade sees such changes which were undreamt of by a previous generation. At the beginning of the twentieth century no heavier-than-air machine had flown, no one had spoken over distances without wires, the moving picture was a visionary experiment. What shall we see by the middle of that century, and who shall say what the world will be like at the beginning of the twenty-first century ?

The coming of wireless telephony at about the same time as the conquest of the air by heavier-than-air machines will have an important effect upon the future of aircraft in many ways. In a former chapter it has been explained how the pilot of a passenger-carrying plane keeps in constant touch with aerodromes and learns all the latest news of the weather or any other news he wishes. It is just as easy to talk to some one on the ground, indeed, as it is to telephone in the ordinary way.

But the wireless telephone will be used more and more for communication in the air itself, between one aeroplane and another. A fleet of aeroplanes, fighting scouts, battle planes, bombers, and so on, during the next great war, will keep in touch with their leader by means of the wireless telephone. Orders will be given from the air with as great ease as now the commander of a battleship at sea communicates his order to any part of his ship. An aeroplane can be detached at a moment's notice from its squadron, while flying at 20,000 feet, to carry out special duty, to go back and report and so on. And such reports will be sent back to ground headquarters, or to the fleet to which the air squadron is attached without

the aeroplane or seaplane landing. The pilots will just 'phone up their fighting chiefs on the ground as they now do Croydon and report and ask for further orders. New forms of wireless communication are rapidly coming into use, as beam wireless, which will make such communication to all intents and purposes secret. The big machines of the future may be flying for several days in the air, with two or more pilots, and reporting regularly to the ground as necessary.

A greater menace of the future is the wireless-controlled aeroplane. Many experiments have been carried out already with such aeroplanes, aeroplanes which are controlled from the ground and made to fly in any direction required, to climb or come down or return to their base at the will of a pilot on the ground. Such wireless-controlled aeroplanes are as yet in their infancy. It is not an improbable prophecy to say that aeroplanes, loaded with bombs, will be directed by wireless over any part of the enemy's territory, and will be able to release their bombs by the movement of a switch many miles away. With the steady improvements of television the time is coming when the wireless aeroplane will actually be able to see where it is going, and the picture seen by its wireless eyes will be transmitted to the observer and pilot on the ground, so that they can very accurately judge the position of the aeroplane, and can even see if it is being attacked, and so manœuvre it. There may, indeed, be many battles in the air with no consequent loss of life, as the aeroplanes are brought crashing to the ground. Such wireless-controlled aeroplanes may well be sent up to attack raiding airships, and be caused to drive bodily into the airship and so destroy

it, their explosive cargo being fired by wireless at the critical moment.

The brain, indeed, reels at the combined possibilities of wireless and flying, and the future can only be dimly realized in this direction. Swift aerial torpedoes, moving at several hundred miles an hour and offering impossible targets to anti-aircraft fire, will be directed through the skies to deal out destruction with a certainty as yet only partly foreseen.

GLOSSARY

THE following glossary gives the meanings of the chief terms used in this book. Other terms are also explained in the text.

AILERON.—A movable control surface on the main planes.

AIRCRAFT.—A general term for all types of air-supported vehicles.

AIRSCREW.—Any type of screw with helical blades for rotating in the air and driving an aeroplane. A propeller is an airscrew working behind the main planes, and a tractor an airscrew working in front of the main planes. Commonly, all airscrews are often spoken of as propellers.

AIR SPEED.—The speed of an aircraft relative to the air, as distinct from its speed relative to the ground.

AMPHIBIAN.—An aeroplane which can alight on land or water.

BIPLANE.—An aeroplane which has a pair of main lifting surfaces above one another.

CEILING.—The greatest height to which an aeroplane can fly.

CRASH.—Term used to describe any accident to an aircraft when alighting on or arising from land or water.

DIVE.—A steep descent with the nose of the aircraft down. A vertical or almost vertical descent is called a nose dive.

DRAG.—The resistance of an aircraft along its line of flight, its head resistance. Also the resistance of any part of the machine, as the drag of the wings.

EDGE.—The leading edge is the front edge of a surface relative to its normal direction of motion. The trailing edge is the rear edge of a surface relative to its normal direction of motion.

FLIGHT PATH.—The path of the centre of gravity of an aircraft in the air.

FLYING BOAT.—An aeroplane which has a main hull-shaped support, like a boat, for floating on, alighting on, or rising from the water.

FLYING LOAD.—*See* LOAD.

Fuselage.—The body of an aeroplane to which the wings and tail plane are attached, and in which the pilot and passengers sit or the load carried is placed.

Glide.—An aircraft is said to glide when it is descending in an ordinary flying attitude with the engine off. A glider is the term used for an engineless aeroplane. The gliding angle of an aircraft is the angle between the horizontal and the path of an aircraft gliding.

Hangar.—A shed in which aeroplanes are housed.

Helicopter.—A form of aircraft which is supported in the air by horizontal airscrews.

Joy Stick.—The general popular name given to the control column of an aircraft, the column which is moved backwards and forwards or sideways as required by the pilot when he wishes to climb or come down or turn.

Leading Edge.—*See* Edge.

Lift.—The force acting on an aircraft perpendicular to the flight path.

Load.—The useful load of an aircraft is the load it carries, apart from those necessary for flight. The gross weight or total flying load is the total weight of the aircraft. Its service load is the weight of the crew, armament and equipment; not part of the permanent structure.

Nose Dive.—*See* Dive.

Performance.—Term used for the speed of level flight, rate of climb and ceiling of an aircraft.

Propeller—*See* Airscrew.

Pusher Aeroplane or Pusher.—An aeroplane in which the airscrew or airscrews are mounted behind the main planes.

Seaplane.—An aeroplane which can alight on or rise from the water. Usually provided with floats, and sometimes called a float plane.

Span.—The over-all distance from wing tip to wing tip of an aircraft.

Spar.—The principal member of the main planes or control surfaces which supports the remaining members.

Stability.—An aircraft is said to be stable if it will return to a state of steady motion in the air after disturbances without movement of the controls by the pilot.

Stalling Speed.—The air speed, which corresponds to the maximum lift of an aeroplane, seaplane or flying boat.

Streamline.—The path of a small portion of fluid, supposed continuous, moving relatively to a solid body. Bodies are said to be streamline when they are so shaped that the paths of all

particles of air flowing past them do not suddenly change direction or form eddies.

Taxying.—An aircraft is said to taxy when it manœuvres under its own power on land or water.

Tractor Aeroplane or Tractor.—An aeroplane in which the airscrew or airscrews are mounted in front of the main planes.

Trailing Edge.—*See* Edge.

Undercarriage.—That part of an aeroplane on which an aeroplane alights.

Useful Load.—*See* Load.

Very Light.—A white or coloured light which is projected from a Very pistol.

PRINTED BY J. AND J. GRAY, EDINBURGH